SECTION 3

HYDRAULIC DISCHARGE MEASUREMENTS ON THE ST. MARYS RIVER

3.1 Below the St. Marys Rapids, 1867.

3.1.1 Purpose.

The determination of the discharge in the St. Marys River was made by the U.S. Lake Survey District, Army Corps of Engineers, in 1867, using double floats. This was part of a basin-wide effort to measure the outflows from all the Great Lakes. Measurements were also made, during 1867, in the St. Clair, Niagara and St. Lawrence Rivers.

3.1.2 Description of Section.

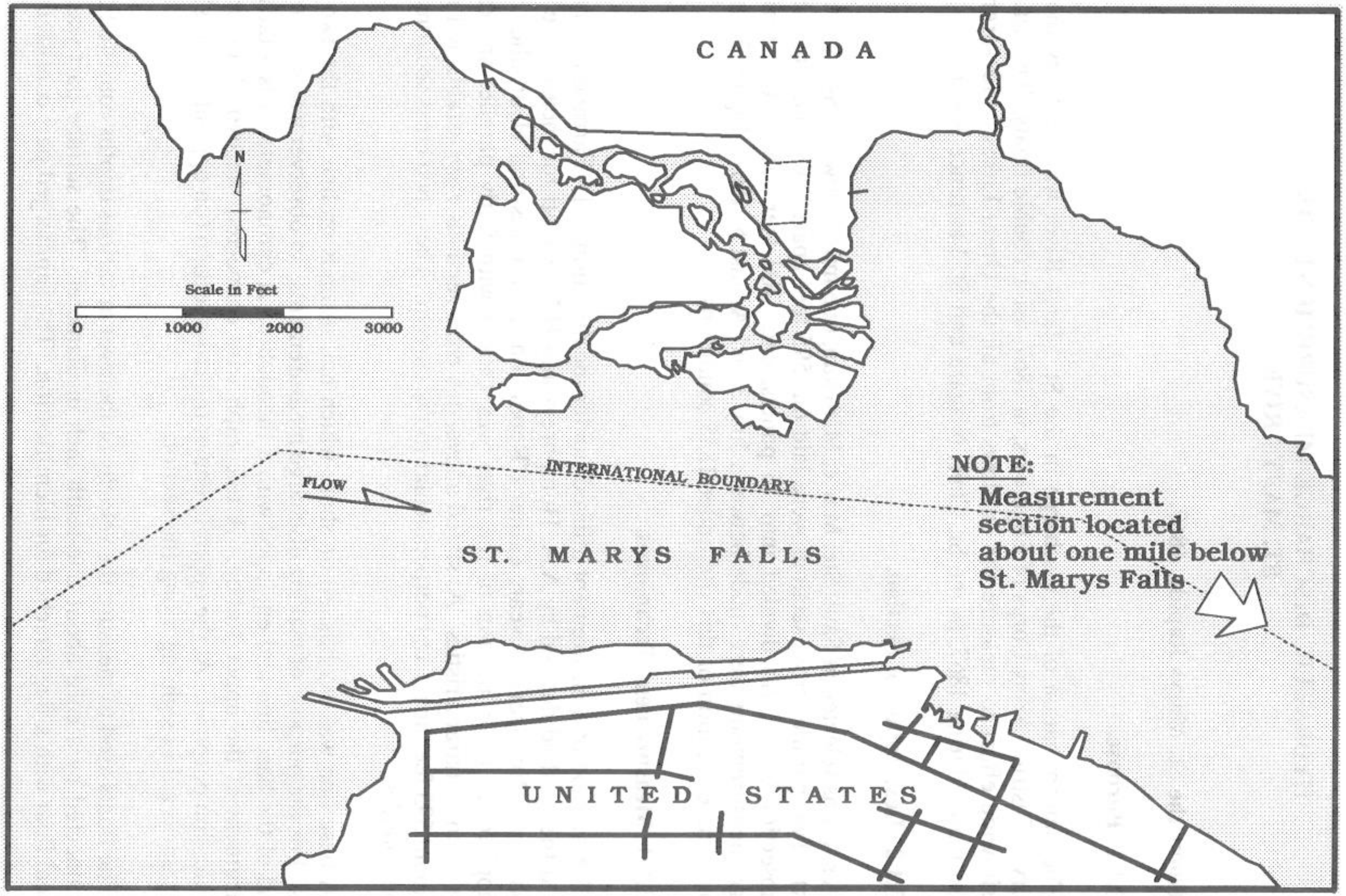
A site was selected at Sault Ste. Marie, Michigan, one mile below the St. Marys Falls (Rapids). Two parallel cross sections were laid out 595 feet apart. A mean cross section (see Subsection 3.1.4) was divided into 16 panels, each 200 feet wide. This series of discharge measurements were made between July 3 and August 5, 1867. Figure 3-1 shows the approximate location of this site under 1855 conditions.

3.1.3 Measurement Techniques.

The method of measurement utilized (under the direction of D. Farrand Henry) was similar to the method devised by A.A. Humphreys and H.L. Abbott for measurements on the Mississippi River several years earlier ("Report on the Physics and Hydraulics of the Mississippi River"). A portion of the river was chosen with fairly parallel shores and uniform bottom characteristics. As stated above, two cross sections were established in this reach, about 595 feet apart and perpendicular to the current. These two cross sections were lead-line sounded.

A base line was established on shore which had its ends on line with the two cross sections. For the purpose of making discharge measurements, an observer was stationed on each end of the base line and equipped with a theodolite. A chronometer was attached to the instrument at the upper station. A telegraph wire connected the two observers, for communication purposes. At the opposite end of the cross section (on opposite shores) flags were set up to aid in sighting along the section.

The floats used to measure the velocity of the river at various depths consisted of two parts connected by a cord about one-tenth inch in diameter. The surface part was a tin ellipsoidal float with a flag attached for identification. The submerged part consisted of an



St. Marys River, Sault Ste. Marie, 1855 Conditions

Figure 3-1

old paint keg with a reel attached, by which its distance from the surface float could be regulated. These floats were set in the river above the upper section, with the lower part at predetermined depths.

At a signal from the observer at the upstream station, a float was released into the river. When the float reached the first section line, the upstream observer signaled the downstream observer, who had been tracking the float in the telescope of his theodolite. He in turn marked the angle made between the base line and the line of sight to the float as it crossed the section line. At the same time, the upstream observer marked the time. The upstream observer then tracked the float past the lower section. When the float crossed the lower section line, the downstream observer signaled the upstream observer, who marked the angle and the time. Because it took, on average, ten minutes for a float to pass between the two section lines, several floats would be released at one or two minute intervals until the first float neared the lower section. Measurements were made at various positions across the river and with the floats adjusted to various depths. Measurements were made at each five feet of depth.

During the period of measurements, a water level gauge was read every two hours. No description or location of this gauge could be found in Henry's report or field notes. The gauge readings, however, give the relative daily fluctuation of the water during the period of measurement.

3.1.4 Discharge Computation.

The soundings of the two cross sections were averaged to obtain a mean cross section. This mean cross section was divided into 16 divisions or panels and an area was computed for each.

The actual distance each float traveled in passing between the sections (as determined from the angles from the base line recorded by the observers) divided by the time required for passage, gave the velocity of the river at that depth and place on the mean section. The daily panel discharge was determined by multiplying the panel area, corrected for stage, by the mean velocity of all the floats that passed through the panel during the day. These daily panel discharges were tabulated and their mean gave the panel discharge for the period. The discharge of the river for the period was obtained by adding together the 16 panel discharges. This value, as determined by Henry, gave the discharge of the river as 90,783 cfs for the period July 3 through August 5, 1867.

At the time Henry made his discharge measurements, little was known about river hydraulics. In his reduction, the mean of all float velocities in the panel was used as the mean panel velocity. This would have given a fairly accurate value for mean panel velocity, if the floats were uniformly spaced across the panel and in the vertical. However, this was not the case. In the 1940s, it was decided that a reduction of the 1867 float measurements according to the U.S. Lake Survey methods of that time would give a better value for the flow.

In 1943, the 1867 measurements were reduced by applying vertical and transverse coefficients to determine the mean velocity in each panel for each day. Because floats were not used in every panel each day, it was necessary to interpolate from the transverse velocity curve the velocities in those panels in which no floats were used. For this reduction, seven panels were used.

For some unknown reason, Henry's section area was not used in the 1943 reduction. Instead, the section area was obtained from a survey of the river made in 1855. It is not clear how the river stages of 1855 and 1867 were correlated, as there was no gauge in 1855, but the section area so obtained, 89,830 square feet, was 15.4 percent greater than Henry's section area of 77,871 square feet, both at the same stage. This discrepancy induced certain errors in the vertical and transverse coefficients as well as in the panel areas. It was thought best to supersede the 1943 reduction.

In 1944, Henry's soundings were replotted on the upper and lower sections, using the original field notes. A mean section was drawn by averaging the upper and lower sections; its area was found to be 78,338 square feet. This area was 0.8 percent greater than that used by Henry, and also served as a check on Henry's work. This mean section was divided into 16 panels, each 200 feet wide, except the end panels. Since these sections were 595 feet apart, it was thought that the mean area of the two end sections might not be a fair approximation of the average section in this reach. Henry's soundings, between the upper and lower sections, were plotted. They were not as numerous as on the sections, but of sufficient number to plot two additional cross sections at one and two thirds the distance below the upper section. The mean of the four sections was taken using the average end area method and the value so obtained was only 0.03 percent greater than that used in the reduction, indicating no appreciable error in the cross sectional area as selected.

A mean vertical curve for Henry's section was selected from a plot of three measured mean vertical curves on sections, whose mean depth compared favorable with the mean depth on Henry's section. The three sections used were: 1) the Spry Dock Section on the St. Marys River, 2) the Dry Dock Section on the St. Clair River and 3) the Three Points Section on the St. Lawrence River. From the selected mean vertical curve, vertical coefficients were determined and each velocity, as determined by Henry's floats, was reduced to a mean vertical velocity.

The mean vertical velocity and position of every float in each panel during the period of measurements was averaged. These points were plotted and a transverse velocity curve drawn through them. Since these points plotted very close to the center of each panel, indicating a balanced distribution of floats along the panel, it was decided to use the average of the mean vertical velocities as the mean panel velocity.

An examination of the water level record indicated that a maximum error of 1 percent in area, in any one day, would result if the daily stage correction was omitted. Since errors due to neglecting changes of stage were so small and would be largely compensating, it was decided to omit daily stage correction.

The discharge in each panel, during the period, was obtained by multiplying the average mean vertical velocity of all floats in the panel by the panel area. The total discharge of the river for the period was obtained by adding together the discharges of all 16 panels of the section. The total flow of the river so determined was 84,200 cfs, which is 7.3 percent smaller than Henry's determination.

Substituting in the 1943 computations the area determined in 1944 resulted in a flow of 81,560 cfs. The difference between the reductions is only 3.2 percent in the mean flow. It seemed, at the time, best to adopt the mean of the two reductions using the 1944 areas: 82,880 cfs.

The 1867 reduction of these measurements is in the Report of the Chief of Engineers, 1868, p.949. Later reductions of these measurements can be found in files 3-222, 3-223, 3-3003, 3-3019 and 3-3149 of the U.S. Lake Survey Archives (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland). Table 3.1 (see Appendix C) summarizes the reductions made by Henry in 1867. Table 3.2 (see Appendix C) gives the results of the recomputations in 1943.

3.2 Bridge Section, 1895-1896.

3.2.1 Purpose.

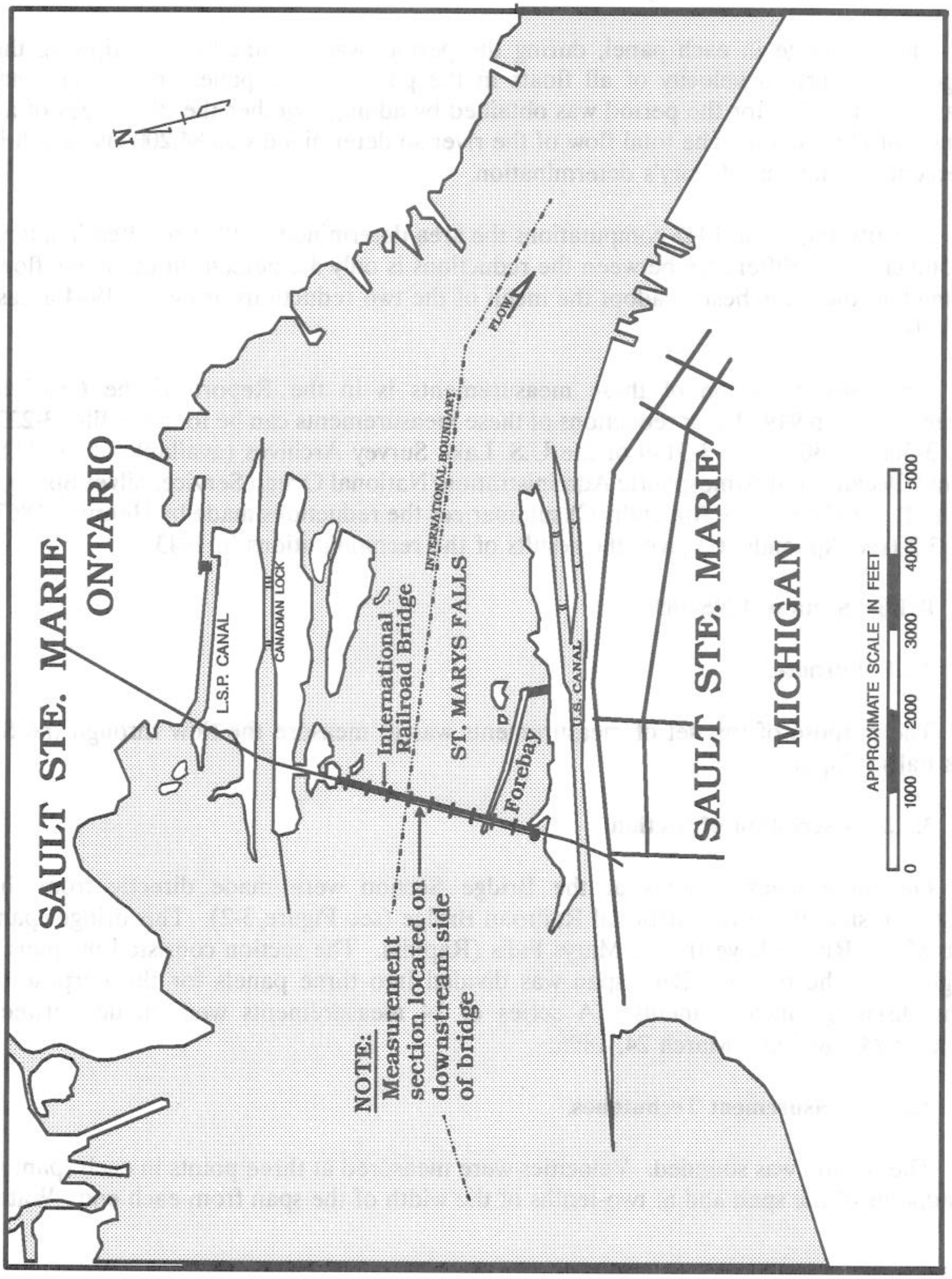
The purpose of this set of measurements was to measure the flow through the St. Marys Falls (Rapids).

3.2.2 Description of Section.

Discharge measurements at the Bridge Section were made directly from the downstream side of the International Railroad Bridge (see Figure 3-2). This bridge spans the St. Marys River above the St. Marys Falls (Rapids). The section consisted of spans 3 through 10 of the bridge. Each span was divided into three panels for the purpose of making discharge measurements. A series of 14 measurements were made between December 24, 1895 and March 24, 1896.

3.2.3 Measurement Techniques.

The section was sounded. Velocities were measured at three points in each span; at the midpoint of the span and at two-tenths of the width of the span from each end. Water



St. Marys River, Bridge Section Location, 1895-1896

Figure 3-2

levels were recorded at the South Abutment gauge, located on the International Bridge near the Chandler-Dunbar Plant forebay.

3.2.4 Discharge Computation.

These measurements were not reduced until 1943. No velocity coefficients had been determined at the time of measurements and the soundings made in 1895 were insufficient to determine the area of the section. When the velocity measurements were reduced to discharge through the section, velocity coefficients and areas used were from a 1901 series of measurements at this section.

To compute the discharge through a panel, the velocity measured at the panel point was multiplied by the velocity coefficient for the panel and the panel area, corrected for the water level at the time of measurement. The total discharge through the section for each discharge measurement was computed by adding the individual panel discharges.

Elevations at the South West Pier (S.W. Pier) gauge corresponding to the measurements were computed in 1943, using the following equation:

S.W. Pier(1935 adj.) = 600.51 + 1.027 * (South Abutment(1877) - 600.00)

The measurements made at the Bridge Section in 1895 and 1896 and reduced in 1943 are summarized in Table 3.3 (see Appendix C). Information on this series of measurements was obtained from the U.S. Lake Survey Archives (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland); files 3-1315 to 3-1318 and 3-3003.

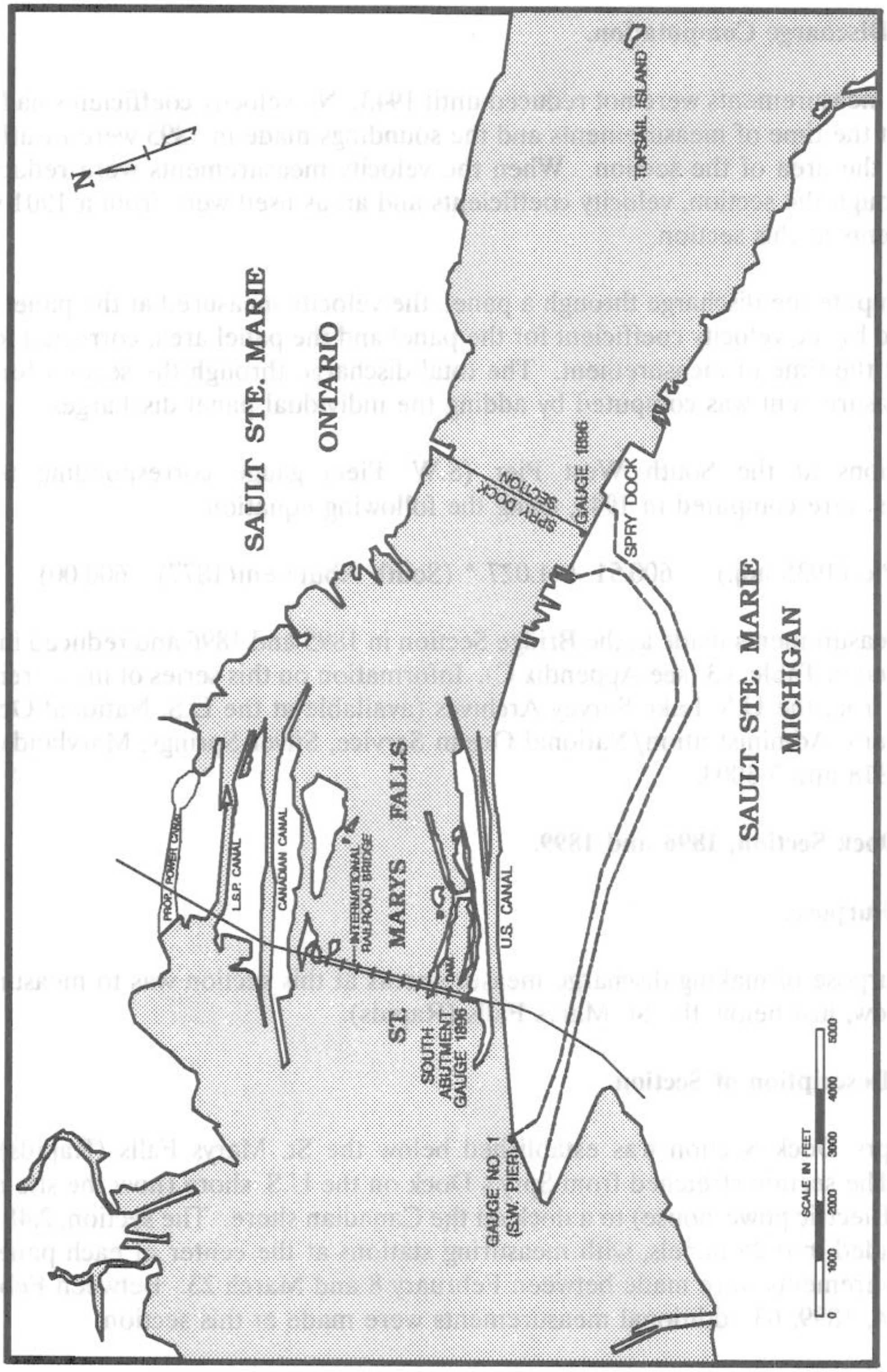
3.3 Spry Dock Section, 1896 and 1899.

3.3.1 Purpose.

The purpose of making discharge measurements at this section was to measure the entire river flow, just below the St. Marys Falls (Rapids).

3.3.2 Description of Section.

The Spry Dock Section was established below the St. Marys Falls (Rapids) (see Figure 3-3). The section stretched from Spry's Dock on the U.S. shore (now the site of the Edison Sault Electric powerhouse) to a dock on the Canadian shore. The section, 2,483 feet wide, was divided into 25 panels, with measuring stations at the center of each panel. In 1896, 54 measurements were made between February 8 and March 23. Between February 18 and April 4, 1899, 63 additional measurements were made at this section.



St. Marys River, Spry Dock Section Location, 1896-1899

Figure 3-3

3.3.3 Measurement Techniques.

All soundings and velocity measurements were made through holes in the ice. The velocities at stations 1-22 were measured using a Haskell, Form E, current meter. Velocities in the three most northern panels were too low for accurate work with the meters and were determined using a hydrometic pendulum.

Discharge measurements were made at the 0.4 depth. Vertical velocity measurements were made coincident with the discharge measurements. Observations of vertical velocity were made one foot from the bottom, one foot from the surface and at nine equidistant points in between. Ten sets of vertical measurements were made at each station (1-22).

Water levels were recorded by a gauge at the section and by the South Abutment gauge on the International Bridge, near the Chandler-Dunbar Plant forebay.

3.3.4 Discharge Computation.

To relate the velocity measured at the 0.4 depth to a mean panel velocity, velocity coefficients were determined for each panel. Using the ten readings at eleven points in the vertical, a mean velocity was determined. The ratio of this mean velocity to the velocity measured at the 0.4 depth gave the coefficient for that panel.

A subsequent velocity measurement made at the 0.4 depth was multiplied by the velocity coefficient to obtain a mean velocity in the panel for that measurement. This mean panel velocity was multiplied by the area of the panel, computed from the soundings and corrected for the water level at the time of the measurement, to get the discharge through the panel. The discharge through each panel was computed separately, then summed to get the total discharge through the section for that observation.

The 1896 measurements, as originally reduced, were corrected for pondage between the measurements section and the foot of the rapids, adjusting the discharges to the South Abutment gauge. The amount of this correction was much less than the probable error of the measurements and of the diversions of water through the power plants and, as such, this correction was later disregarded.

The water levels at the South Abutment gauge were, at a later date, converted to levels at Gage No.1 (S.W. Pier gauge), at the west end of the southwest pier of the U.S. navigation locks. This was done by adding +0.205 feet, for the slope between the South Abutment gauge and Gage No.1, and +0.197 feet, for adjustment to 1903 Datum.

Tables 3.4 and 3.5 (see Appendix C) summarize the discharge measurements made at the Spry Dock Section in 1896 and 1899. A detailed report on the 1896 measurements was released as part of the 1897 Report to the Chief of Engineers, page 4092. Limited information concerning these measurements is located in the U.S. Lake Survey Archives, files 3-1315, 3-1362 and 3-1767 (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland).

3.4 International Bridge Section, 1899-1902.

3.4.1 Purpose.

From August 1901 to November 1901, a breakwater and cofferdams were constructed upstream of the International Railroad Bridge on the St. Marys River. The purpose of these structures was to permit construction of four compensating gates adjacent to the Canadian shore. The breakwater and cofferdams reduced the flow through spans 9 and 10 of the bridge.

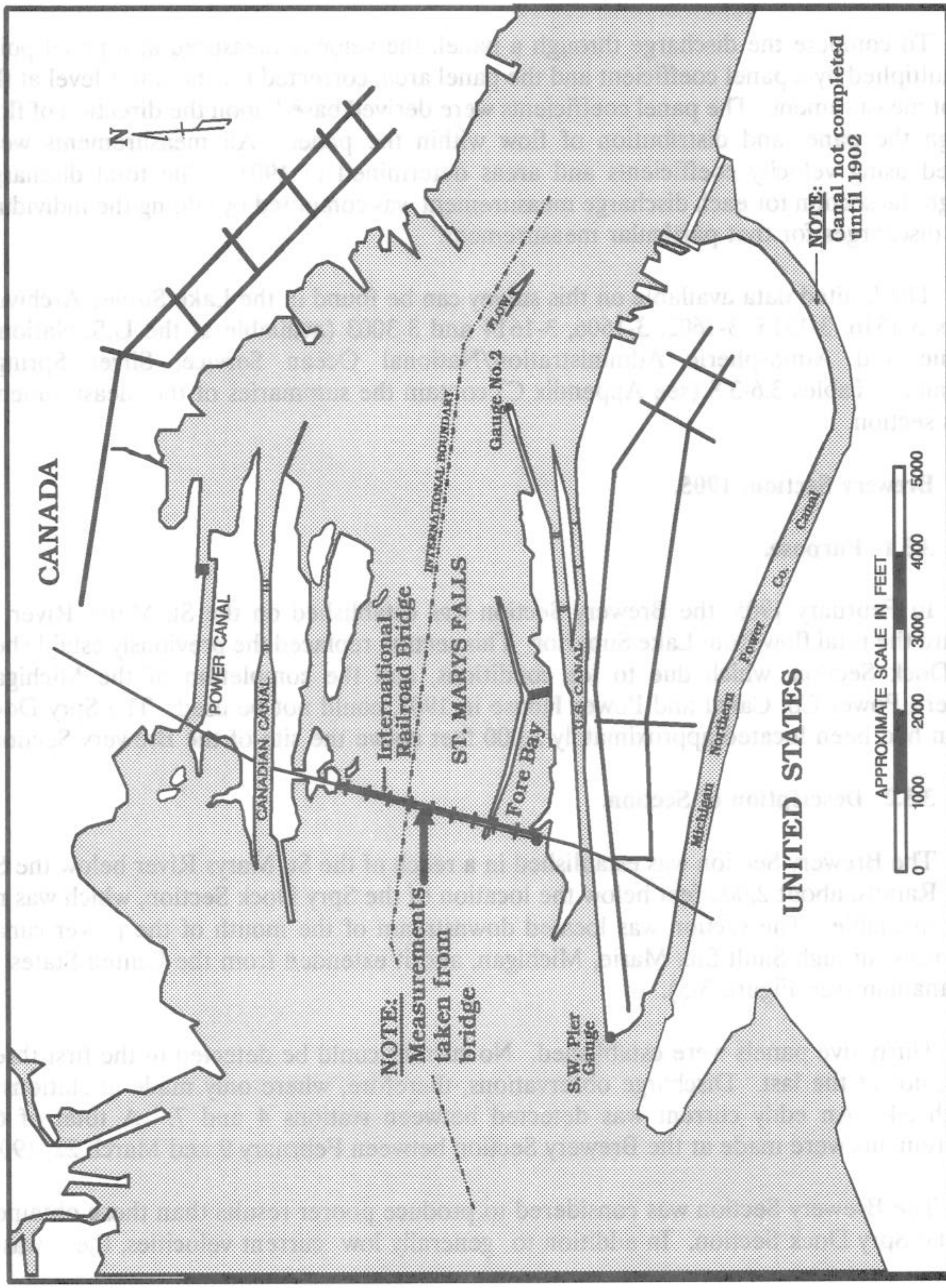
Discharge measurements were made both before and after construction, to determine the effect on the St. Marys Rapids flows of closing off the ninth and tenth spans of the bridge. A series of discharge measurements were made from the International Bridge, in 1899. Measurements were again made in July 1901. Due to the large quantities of pulp wood jammed on the bridge piers at the time of the July 1901 measurements, they were not considered to be representative of the rapids flow. Measurements were also made after construction was completed in 1901 and again in 1902, but no records of the resulting discharge computations were recovered.

3.4.2 Description of Section.

Hydraulic measurements at this section were made directly off of the International Railroad Bridge (see Figure 3-4). This bridge spans the St. Marys River and connects Sault Ste. Marie, Michigan, and Sault Ste. Marie, Ontario. The section consisted of ten bridge spans, but discharge measurements were made in only eight; spans 3 through 10. A total of 33 measurements were made at this section between December 4 and 27, 1899. During the summer of 1901, the construction of the cofferdams above spans 9 and 10 was in progress. The measurements were continued through the period of construction. Twenty measurements were made in July-August, before the construction had affected the flow, and 44 measurements were made after the work had been completed. In 1902, 146 additional measurements were made.

3.4.3 Measurement Techniques.

The section was sounded for the 1899 survey. Each span was divided into three panels, for the purpose of making discharge measurements. Water levels recorded at the Southwest (S.W.) Pier gauge were used to reduce the velocities through the panels to discharges. The S.W. Pier gauge was an automatic recording gauge located near the west end of the Southwest Pier at Sault Ste. Marie, Michigan. Water levels were also recorded



St. Marys River, International Bridge Section, 1899-1902

Figure 3-4

downstream of the section at Gauge No.2. This gauge was located at the east tip of the north pier of the U.S. locks.

3.4.4 Discharge Computation.

To compute the discharge through a panel, the velocity measured at a panel point was multiplied by a panel coefficient and the panel area, corrected for the water level at the time of measurement. The panel coefficients were derived based upon the direction of flow through the panel and distribution of flow within the panel. All measurements were reduced using velocity coefficients and areas determined in 1901. The total discharge through the section for each discharge measurement was computed by adding the individual panel discharges for that particular measurement.

The limited data available on this survey can be found in the Lake Survey Archives, in files 3-1516, 3-1515, 3-1602, 3-1606, 3-1614 and 3-3003 (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland). Tables 3.6-3.8 (see Appendix C) contain the summaries of the measurements at this section.

3.5 Brewery Section, 1905.

3.5.1 Purpose.

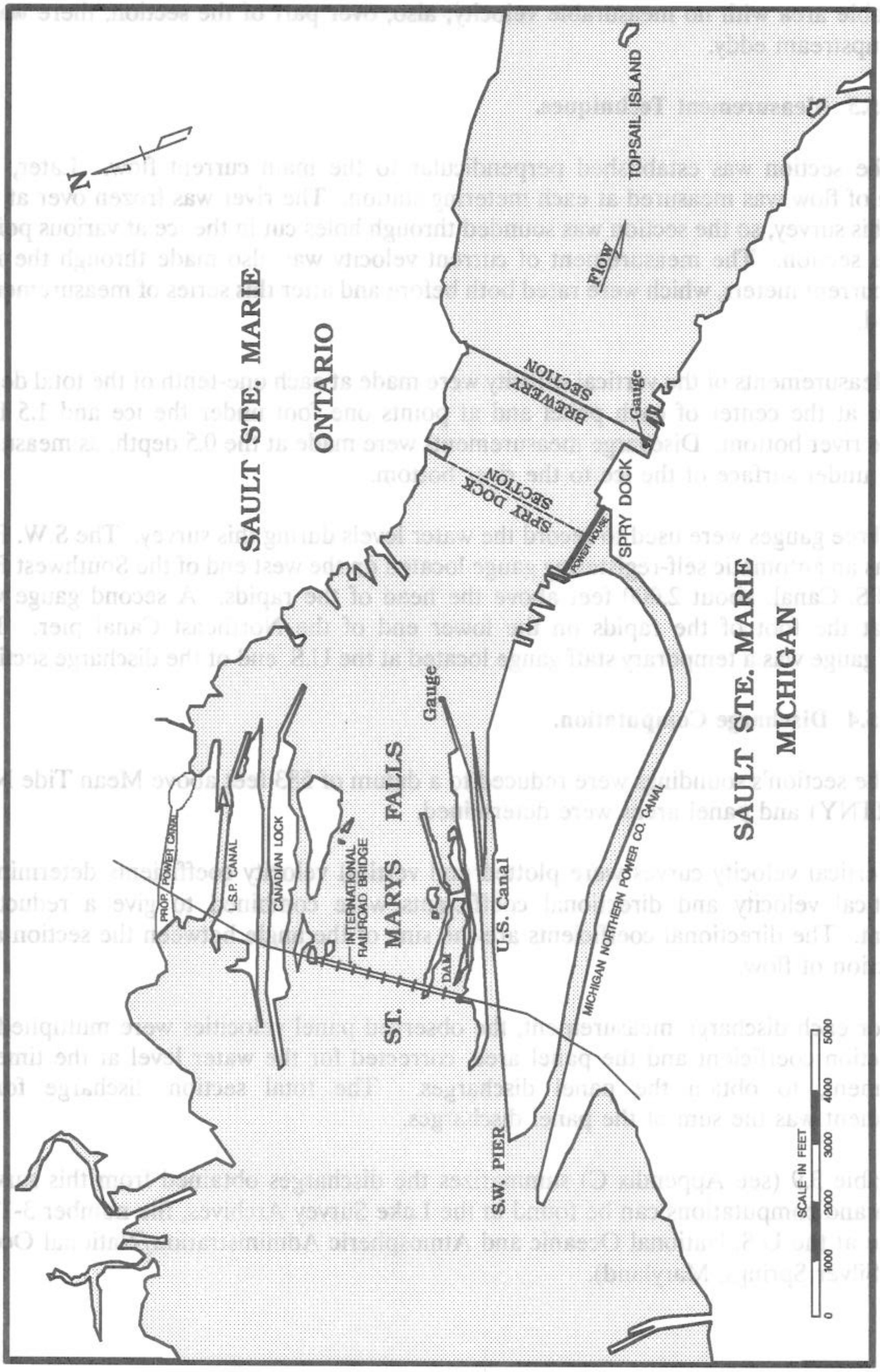
In February 1905, the Brewery Section was established on the St. Marys River to measure the total flow from Lake Superior. This section replaced the previously established Spry Dock Section, which due to ice conditions, and the completion of the Michigan Northern Power Co. Canal and Power House in 1902, could not be used. The Spry Dock Section had been located approximately 2,000 feet above the site of the Brewery Section.

3.5.2 Description of Section.

The Brewery Section was established in a reach of the St. Marys River below the St. Marys Rapids, about 2,000 feet below the location of the Spry Dock Section, which was no longer available. The section was located downstream of the mouth of the power canal, which runs through Sault Ste. Marie, Michigan, and it extended from the United States to the Canadian (see Figure 3-5).

Thirty-five panels were established. No current could be detected in the first three panels, nor at the last. Discharge observations, therefore, where only made at stations 4 through 34. An eddy current was detected between stations 4 and 7. A total of 60 measurements were made at the Brewery Section between February 9 and March 22, 1905.

The Brewery Section was considered to produce poorer results than those obtained from the Spry Dock Section. In addition to generally low current velocities, there was a



St. Marys River, Brewery Section

Figure 3-5

considerable area with no measurable velocity; also, over part of the section, there was a variable upstream eddy.

3.5.3 Measurement Techniques.

The section was established perpendicular to the main current flow. Later, the direction of flow was measured at each metering station. The river was frozen over at the time of this survey, so the section was sounded through holes cut in the ice at various points along the section. The measurement of current velocity was also made through the ice; Haskell current meters, which were rated both before and after this series of measurements, were used.

Measurements of the vertical velocity were made at each one-tenth of the total depth measured at the center of each panel and at points one foot under the ice and 1.5 feet above the river bottom. Discharge measurements were made at the 0.5 depth, as measured from the under surface of the ice to the river bottom.

Three gauges were used to record the water levels during this survey. The S.W. Pier gauge was an automatic self-registering gauge located on the west end of the Southwest Pier of the U.S. Canal, about 2,000 feet above the head of the rapids. A second gauge was located at the foot of the rapids on the lower end of the Northeast Canal pier. The section's gauge was a temporary staff gauge located at the U.S. end of the discharge section.

3.5.4 Discharge Computation.

The section's soundings were reduced to a datum of 583 feet above Mean Tide New York (MTNY) and panel areas were determined.

Vertical velocity curves were plotted and vertical velocity coefficients determined. The vertical velocity and directional coefficients were combined to give a reduction coefficient. The directional coefficients are the sine of the angle between the section and the direction of flow.

For each discharge measurement, the observed panel velocities were multiplied by the reduction coefficient and the panel area, corrected for the water level at the time of measurement, to obtain the panel discharges. The total section discharge for a measurement was the sum of the panel discharges.

Table 3.9 (see Appendix C) summarizes the discharges obtained from this survey. The data and computations can be found in the Lake Survey Archives, file number 3-1767 (available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland).

3.6 International Bridge, Bingham Ave., Float, Bridge and Lake Superior Corporation Sections, 1909.

3.6.1 Purpose.

The outflow of Lake Superior is controlled by the natural weir formed by the St. Marys Rapids and by the amount of water permitted to the power companies. The purpose of this set of measurements was to measure the Lake Superior outflow by measuring the flow over the rapids and through the powerhouses.

3.6.2 Description of Sections.

The **International Bridge Section** (see Figure 3-6) was recovered from the 1901-1902 survey. Measurements were made of the flow through spans 3 to 10 of the International Railroad Bridge. Each span was divided into three panels. Between September 18 and 27, 1909, 30 discharge measurements were made.

The bridge location was a poor choice for a hydraulic section to measure discharge. The section was so shallow that few observations could be made on the vertical curves below the 0.8 depth, and in many cases not below the 0.6 depth. The swift current between the bridge piers endangered the meters. It was also difficult to rate the meters at such high velocities. A combination of the fast current and the obstruction of flow by the bridge piers created a situation whereby the water surface between the piers was not level. The proportional rise and fall at different points within a span sometimes differ by as much as 100 percent at any one time.

Four other hydraulic sections were established for this survey. Their purpose was to measure the discharge in the power canals, so that relationships for converting powerhouse output in kilowatts (KW) to cfs could be determined.

The **Bingham Ave. Section** (see Figure 3-6) was used to measure the flow through the Michigan Lake Superior Power Company (now Edison Sault Electric Company) powerhouse. The section was established on the eastern edge of the Bingham Avenue bridge over the power canal which runs through Sault Ste. Marie, Michigan. The bridge crosses the canal at right angles, about 4,500 feet above the powerhouse. Between August 19 and 21, 1909, 29 discharge measurements were made at this section.

To measure the flow through the Edison Sault Electric Company's powerhouse (now the U.S. Government power plant), the **Float Section** (see Figure 3-6) was established on a straight stretch of the plant's headrace, near its lower end. Unlike the usual hydraulic section, the Float Section was three dimensional, having length as well as width and depth. Thirty-seven measurements were made at this section on August 24 and 25, 1909.

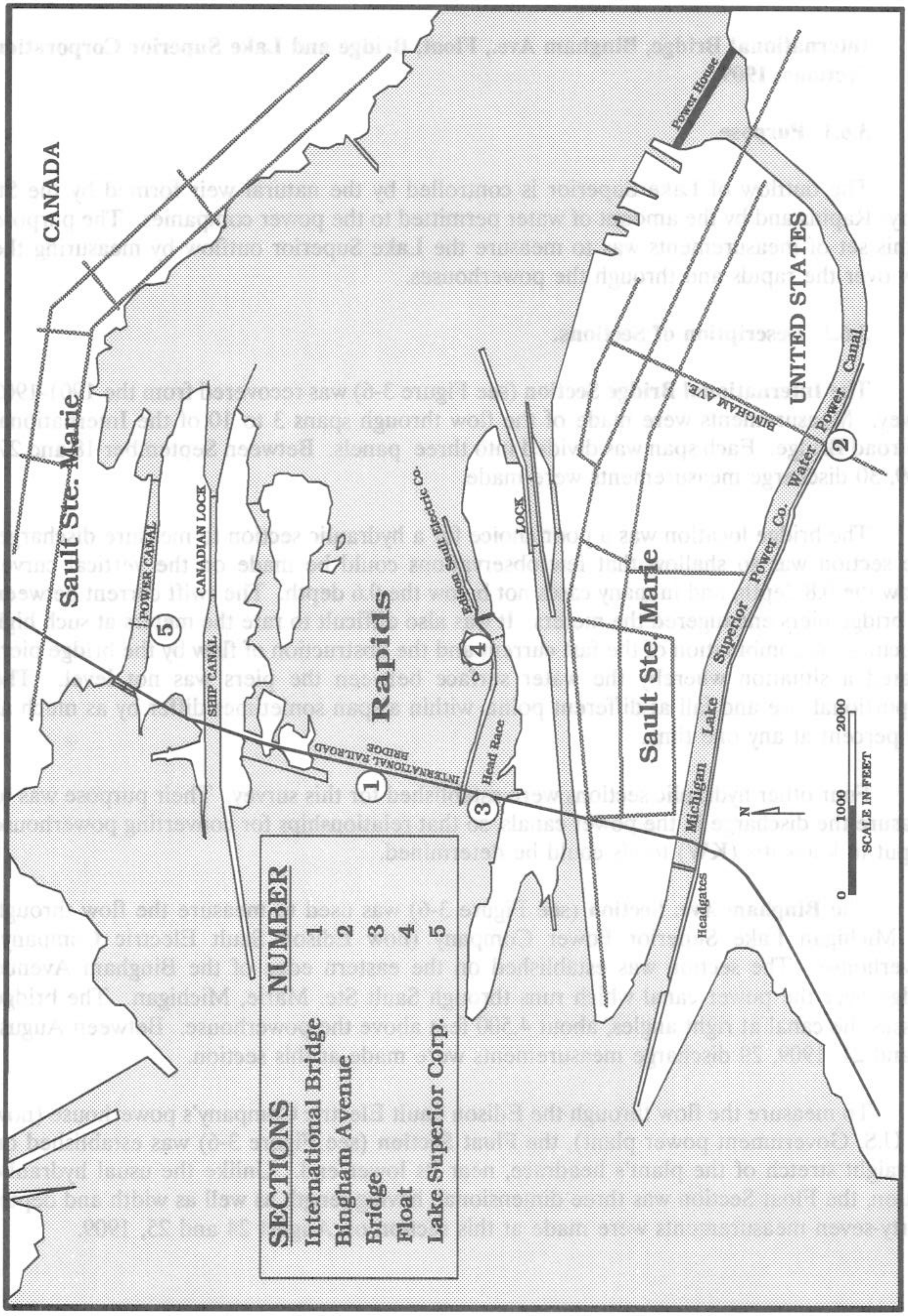

CANADA
Sault Ste. Marie
POWER CANAL
CANADIAN LOCK
SHIP CANAL
Rapids
INTERNATIONAL RAILROAD BRIDGE
Head Race
Edison Sault Electric Co.
LOCK
Sault Ste. Marie
UNITED STATES
BINGHAM AVE
Michigan Lake Superior Power Co. Water Power Canal
Power House
Headgates
N
0 1000 2000
SCALE IN FEET
SECTIONS NUMBER
International Bridge 1
Bingham Avenue 2
Bridge 3
Float 4
Lake Superior Corp. 5
St. Marys River, Sault Ste. Marie, 1909

Figure 3-6

As a rough check on the amount of leakage through the banks of the Edison Sault power canal and on the Float Section measurements, the flow through spans 1 and 2 of the International Railroad Bridge was measured. The section was called the **Bridge Section** (see Figure 3-6). Span 1 was considered as a single panel and a metering point was established 190 feet from the south end. Span 2 was considered as two panels, divided 100 feet from the south end. Between September 16 and 21, 1909, eight discharge measurements were made at this section.

The **Lake Superior Corporation Section** (see Figure 3-6) was established on the Canadian Company's power canal, about 1,300 feet above the powerhouse. The section was 151 feet wide and 12 feet deep. For this survey, the section was divided into eight panels and 20 measurements were made between September 3 and 7, 1909.

3.6.3 Measurement Techniques.

While the bottom of the river, which is solid rock, did not change during the measurements, the water surface profile did. During these measurements dumping above the northwest pier was in progress. Unfortunately no record of the extent of this work at the time of measurement can be found.

The International Bridge Section was not sounded for this survey. It was felt that the cross sections from the 1901-1902 survey were sufficient. A platform was built at each metering point to provide a base from which to make measurements. The elevation of each of these platforms was determined by instrumental levels and they served as a datum to which the water surface at the metering station was referred. Two recording gauges were also temporarily installed, one on Pier 2 and one on Pier 9. During each measurement, Haskell velocity meters were used to make 2-minute observations at the 0.5 depth of each meter station.

The Bingham Ave. Section was sounded using a meter weight. The bottom was practically level except for what appeared to be an accumulation of sand near the southern side. Ten sets of vertical velocity measurements were made in the section. Based on these measurements, eight panels and corresponding metering stations were established. Discharge measurements were made at the 0.4 depth at each metering station.

The flow through the headrace of the Edison Sault Electric Company was relatively low, so it was decided to use rod floats to measure the velocity in the canal. A base of 100 feet (length) was laid out on the northern side of the canal. The section was sounded in ten foot squares by means of a pole and tag line. Eleven cross sections, ten feet apart, were then chosen and depths sounded. The results were combined into a single cross section with the width equal to the mean width and the depths equal to average depths.

The rod floats used at the Float Section were octagonal poles two inches in diameter and of varying lengths. They were weighted at one end with lead so that they would float in a vertical position, with a small portion projecting above the water surface. Tag lines were stretched across the canal at the ends of the section and the floats were timed between the tag lines.

Two series of measurements were made. For the A series (measurements 1-26 and 37), a discharge measurement consisted of the timing of eight floats, starting from the upstream tag line at points 20, 35, 50, 70, 95, 115, 130 and 140 feet from the north bank. The B series, introduced to strengthen the transverse velocity curve and used to make measurements 27 and 36, used ten floats, starting 20, 30, 40, 50, 70, 90, 110, 120, 130 and 140 feet from shore. For both series, the position of each float was read as it crossed each tag line. The path of the float between the tag lines was considered to be straight. The location along the width of the section, where each float crossed the tag lines, was recorded. The mean location of a float for all measurements was determined and used as the point in the mean cross section, which was occupied by the float.

The flow through the first two spans of the International Railroad Bridge was not easily measured by current meters; the flow generally being too low. In 75 percent of the width of Span 1, a Haskell meter could not be used. The same was true for 30 percent of Span 2. To measure the velocity in the three panels of the Bridge Section, three meters were run simultaneously, one at each index point; and floats, consisting of thin, narrow strips of wood, weighted at one end with spikes, were timed from the upper to the lower chord of the bridge, a distance of 21.8 feet. Points were chosen about 20 feet apart over the whole width of the section, and two floats were started from each point. The position of each float, as it crossed the lines of the guard timbers of the bridge, and the time it took to do so, were recorded. Over the portion of the section where measurements with the meters were considered accurate, the velocity given by the floats was disregarded and were used only to give the direction coefficient. Over the portion of the section with velocities too low for meter measurements, the velocity given by the floats was utilized.

At the Lake Superior Corporation Section, a cableway consisting of a single steel wire supported at each end by A-frames was used to make the measurements. A car was built to run underneath the cable. The meters mounted on the car entered the water three feet apart and observations were made from the south bank. The section was sounded with a 50 pound weight and a metallic tape. Soundings were made every 2.5 feet and the tape was read by a level on the shore. Vertical velocity curves were measured at the center of each of the eight panels. The usual methods of discharge measurement and reduction were followed.

3.6.4 Discharge Computation.

At the International Bridge Section, the velocity coefficients determined in 1901-1902 were used to reduce the 1909 observations. The discharge measurements were reduced in the same manner as in 1901-02.

The discharge measurements at the Bingham Ave. Section were also reduced in the usual manner, as typified by the 1901-02 measurements. To determine a factor for the number of kilowatts output per cfs of flow through the Michigan Lake Superior Power Company Plant, the head and output were plotted for each hour and curves drawn through the observations. From these curves, the mean head and mean output were scaled during each discharge observation. The number of kilowatts per cfs was determined for each measurement and an average factor was determined for all measurements.

At the Float Section, the velocity of each float was determined by dividing the length of the base (100 feet), by the time it took the float to pass from one tag line to the other. As the paths of the floats were not normal to the ends of the section, the velocities were adjusted by the cosine of the angle between the path of the float and the normal to the ends of the section. This gives the observed velocity at each point. Owing to the irregular bottom, the floats occupied only about 65 percent of the depth. As a basis for correcting the observed velocity to the mean velocity in the vertical, a vertical velocity curve derived from vertical velocity measurements made in the canal of the Niagara Falls Power Company in 1907 was used. The correction to the observed velocity is the area of that portion of the curve covered by the float, divided by the total area of the curve. The mean velocity in the vertical at each float station was plotted to form the transverse velocity curve. From this curve the velocity was corrected by a transverse velocity coefficient. The output from the Edison Sault powerhouse for each discharge measurement was scaled from curves constructed by plotting the half-hourly readings of the output with respect to time.

At the Bridge Section, the observed float velocities were reduced to percentages of the index velocity, by dividing them by the velocity recorded simultaneously by the meter at the index of the panel through which they passed. The mean vertical velocity from the vertical curves was reduced to the same basis and corrected for direction. These percentages were plotted to form the transverse velocity curve. The mean ordinate to the transverse velocity curve in each panel represents the mean velocity in that panel as a percent of the index velocity. These coefficients were weighted with respect to the area of the panel, to give the velocity coefficient for the panel. This coefficient was multiplied by the observed velocity to get the discharge through the panel. The panel discharges were summed to give the section discharge.

At the Lake Superior Corporation Section, the usual method of discharge reduction was followed.

A summary of all the discharge measurements made for this survey is given in Tables 3.10 to 3.14 (see Appendix C). The report that was written to document this survey can be found in the Lake Survey Archives, available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland, file number 3-1977.

3.7 Compensating Works, 1927-1930.

3.7.1 Purpose.

The Compensating Works, located above the St. Marys Rapids, were completed on August 12, 1921 and, as a result, total regulation of Lake Superior's outflow was achieved at that time. In order to manage the amount of water flowing through the Compensating Works, it was important to calibrate these Works; that is, to determine how much water flows through them at various gate settings and combinations of gate settings.

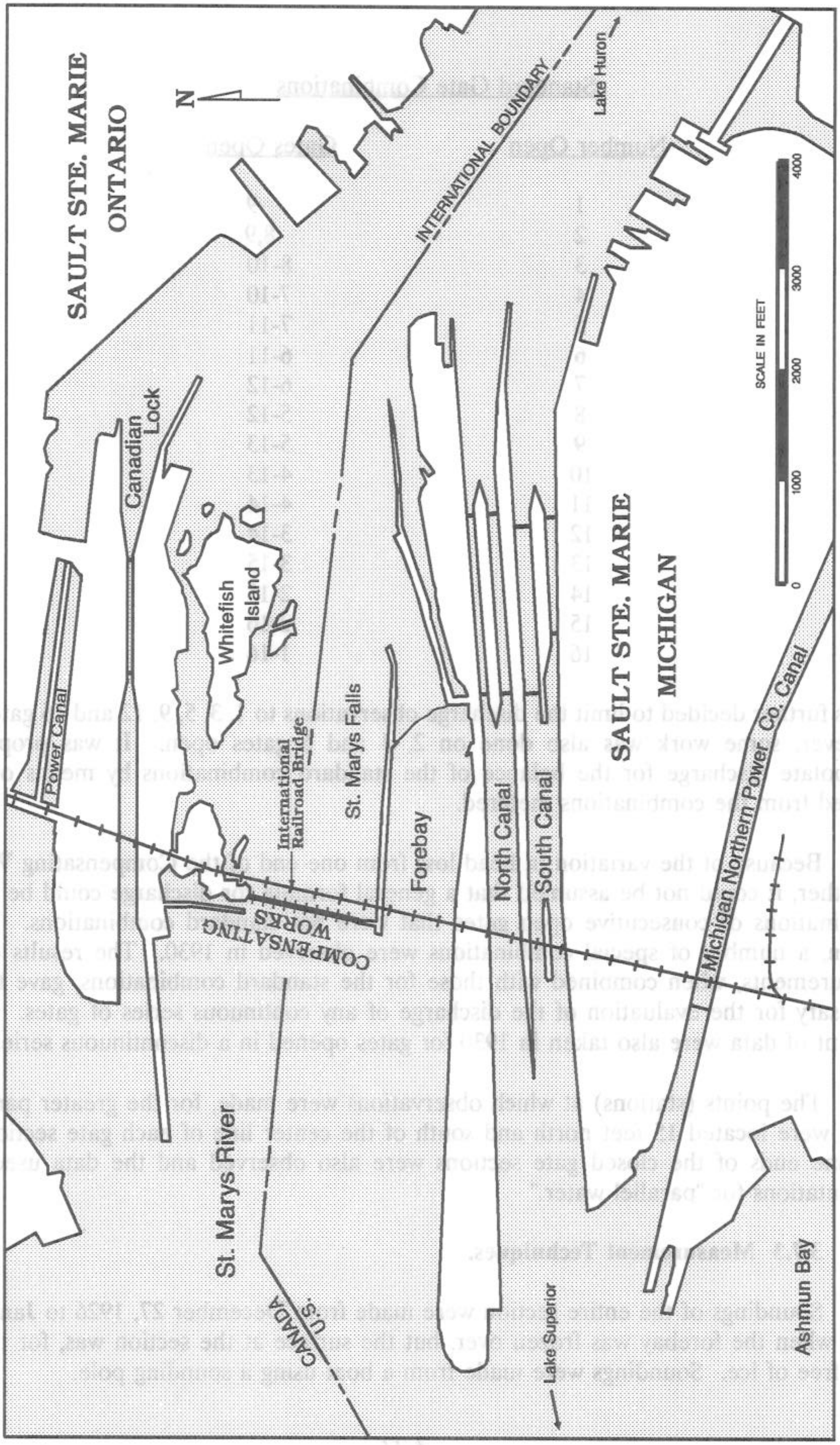
Measurements of the flow through the gates of the Compensating Works began in 1921 and continued at various times into 1930. However, prior to 1927 there was comparatively little work done; methods used for observation were inferior to those employed subsequent to that date. It was felt that the early measurements were not reliable and so they are not included here.

3.7.2 Description of Section.

The Compensating Works consist of 16 Stoney sluice gates with 52.2-foot openings between concrete and masonry piers. The structure is located on a line parallel to and 150 feet upstream of the International Railroad Bridge (see Figure 3-7). Water flowed around the end of the northwest pier and approached the gates from a general southwesterly direction. Much of the flow was concentrated in the deeper portions of the channel at the south side of the forebay, thereby, the greater discharge through the south end gates.

The discharge section, for all measurements made during the period 1927-1929 and for the consecutive measurement series made in 1930, was located about 38.5 feet upstream from the base line of the gates. For any particular combination of gates opened in consecutive order, the section traversed, for velocity and surface elevation, included one closed gate section at each side of the opening. At the extreme ends of these closed gate sections, the angle between the direction of current and the line of the section became quite small. At the ends of the closed gate sections, "parallel water" panels were established at right angles to the main section.

It was decided, in 1927, to limit the discharge openings, as far as possible, to gates in a continuous series, symmetrical about the center line of the Compensating Works. These "standard" gate combinations were those as listed in the table below.



St. Marys River, Compensating Works Location

Figure 3-7

<u>Standard Gate Combinations</u>

Number Open	Gates Open
1	9
2	8,9
3	8-10
4	7-10
5	7-11
6	6-11
7	6-12
8	5-12
9	5-13
10	4-13
11	4-14
12	3-14
13	3-15
14	2-15
15	2-16
16	1-16

It was further decided to limit the discharge observations to 1, 3, 5, 9, 12 and 16 gates open. However, some work was also done on 2, 4 and 6 gates open. It was proposed to interpolate discharge for the balance of the standard combinations by means of curves derived from the combinations metered.

Because of the variation in head loss from one end of the Compensating Works to the other, it could not be assumed that a general formula for discharge could be used on combinations of consecutive open gates that were not standard combinations. For this reason, a number of special combinations were observed in 1930. The results of these measurements, when combined with those for the standard combinations, gave the data necessary for the evaluation of the discharge of any continuous series of gates. A small amount of data were also taken in 1930 for gates opened in a discontinuous series.

The points (stations) at which observations were made, for the greater part of the work, were located 15 feet north and south of the center line of each gate section. The extreme ends of the closed gate sections were also observed and the data used in the computations for "parallel water."

3.7.3 Measurement Techniques.

Soundings of the entire section were made from December 27, 1926 to January 15, 1927, when the forebay was frozen over, but the surface at the section was, for the most part, free of ice. Soundings were made from a boat using a sounding pole.

Prior to making discharge measurements, vertical velocity measurements were made at the 0.2, 0.4, 0.6 and 0.8 depths. This work showed that an average of the 0.2 and 0.8 depths was sufficient to obtain the velocity in the vertical. Therefore, all velocities were measured at the 0.2 and 0.8 depths.

Haskel current meters were used for all of the measurements prior to 1930. A meter was suspended at a station, from a cable stretched over the section and equipped with adjusting screws for taking up slack. Opposite each concrete pier, support was given by means of long wooden outriggers guyed back to the superstructure. A trolley was designed to carry the meter, allowing movement back and forth along the section, and for the setting of selected depths.

The usual procedure, for observing velocity and current direction at a station, was used to lower the meter to the surface, so that it was half submerged. The direction of the current was observed and the angle measured. The meter was lowered to the 0.2 depth and a one minute reading was made. The meter was then lowered to the 0.8 depth, where two consecutive one minute readings were made. On the way up, the 0.2 depth was observed a second time and a second observation of current direction was made at the surface. It was necessary to open each combination of gates from three to four times at different stages, in order to get a sufficient range of measurements.

The section gauge was at Pier No.4 and consisted of a spike set into the masonry. Readings were taken with a graduated stick secured to the spike. The gauge was read at one minute intervals, while velocity observations were being made. The water level elevation for an entire discharge was taken as the mean of the Pier No.4 elevations for the individual station measurements. The S.W. Pier elevations, given in the summary tables for this series of measurements, were obtained by a gauge relationship with Pier No.4 and do not represent actual readings at the S.W. Pier gauge during the periods of discharge measurements.

After the completion of work in 1929, a preliminary report was prepared. While making this report, it became apparent that the results computed for one and two gates open were too high. It was decided to take further measurements at the downstream face of the gates where the flow is practically perpendicular to the base line. Here the Haskell current meters could not be used, because of the high velocities and turbulent flow. To meet these conditions, a Pitot tube was designed. The tube consisted of a 1-1/4 inch pipe clamped to the downstream face of the gate, with additional support from an upstream cable. The nozzle was approximately 1-1/4 inches in diameter with a 6-inch offset. A diaphragm with a 1/8 inch opening was inserted into the pipe, just above the nozzle, to quiet the fluctuations and a vertical blade tail served to hold the tube into the current. Short nipples, closed by threaded caps, were provided at intervals along the tube, and the one most conveniently located was connected by rubber tubing to a gage glass, held by the observer against a gage stick that rested on a "datum". The fluctuations of the water in the glass were gradual, so that there was no difficulty in making readings. Simultaneous with this reading, a second observer read the distance from the datum to the water surface. The sum of these two readings gave the height for the simulation of velocity ($h = V^2 /2g$).

The Pitot tube measurements were made from the gates themselves. Before taking any observations, the gate was lowered as near to the surface as possible, without dragging, and leveled. For the work with one to three gates open, nine stations per gate were observed at the 0.2 and 0.8 depths. In the turbulent flow below the end contractions, the tube ordinarily indicated no velocity at or near the surface. However, under this disturbance it gave consistent readings, indicating streamline flow. A check on the Pitot tube was made by making a number of comparisons between meter and tube measurements on the section. The results were practically identical.

3.7.4 Discharge Computation.

The mean velocity in the vertical was computed as the mean of the velocities measured at the 0.2 and 0.8 depths. In all panels, except the end panels, the mean velocity was multiplied by the sine of the angle between the direction of current and the base line, to obtain the velocity normal to the section. For the end panels, the mean velocity was adjusted by a coefficient determined for parallel water. This coefficient represents the relation between the mean vertical velocity at the end station, on the main section line, and the mean velocity for the panel, connecting the main section with the nose of the pier.

The velocity normal to the panel was multiplied by the panel area to get the discharge through the panel. The panel discharges for a particular measurement were added to get the discharge through the entire section.

As a result of the 1930 work on one to three gates open, the discharge line previously established for one and two gates, was lowered slightly, but the results for three gates agreed well with the previous work.

The results of the discharge measurements made on the standard gates-open combinations are given in Table 3.15. The results of the 1930 Pitot tube work on non-standard gate settings are given in Table 3.16. Current meter observations on the special combinations of gates, are given in Table 3.17. These tables can be found in Appendix C. A 1931 report on these measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file 3-4161, of the Detroit District, Corps of Engineers, Detroit, Michigan.

3.8 Bingham Ave, Edison Sault Tailrace, Canadian Power Canal, Little Rapids and Garden River Sections, 1935.

3.8.1 Purpose.

The monthly outflow from Lake Superior, as published by the U.S. Engineer Office, depended upon the ratings of the three power plants existing at that time, a record of water used in lockage and the calibration of the compensating works. As such, the purpose of the 1935 hydraulic work was to check the calibrations upon which the river discharge was based. The project was, specifically, to test the computed flow through the compensating gates for a small and large discharge and to check one point on the rating of each power plant.

3.8.2 Description of Sections.

To meter the Michigan Northern power canal flow, the **Bingham Ave. Section** was recovered from the 1909 survey. In 1909, the Michigan Northern power plant was owned by the Michigan Lake Superior Power Company. This powerhouse is now owned by the Edison Sault Electric Company. The section was divided into eight panels and six measurements were made during the period August 5-7, 1935.

For the 1909 rating of the Edison Sault Electric Company power plant (now the U.S. Government Plant), the Float Section was established. The measurements were made at the entrance to the penstocks. Metering at that location necessitated special equipment. It was undesirable to use the same method for the 1935 project. An alternative measurement location was chosen in the tailrace, the **Edison Sault Tailrace Section,** about one-quarter mile east of the plant. Due to the nature of the Edison Sault load, there was considerable fluctuation in the tailrace flow, but the results were fairly consistent. Sixteen discharge measurements were made at this section between August 8 and 12, 1935.

To get an overall check on the ratings of the Great Lakes Power Plant and the Abitibi Groundwood Mill, the **Canadian Power Canal Section** was established in the headrace of the Canadian power canal. The section was metered using a previously established cableway. Four panels were metered in the section. Between August 13 and 20, 1935, eighteen measurements were made.

Previous measurements of the rapids flow had been made from the International Railroad Bridge. In 1935, with the presence of the compensating works above the bridge, this was no longer feasible. As an alternative to measure the rapids flow, the total flow in the river was measured for this survey. To do this, the below noted two sections were established downstream of the rapids. Measurements were made with 3, 8 and 12 gates open.

The **Little Rapids Section** was located three miles below Sault Ste. Marie, Michigan, at the upper end of Little Rapids Cut. The section was approximately 750 feet wide and 27 feet deep, and was divided into six panels. In connection with this section, it was necessary to measure four side flows. One was through a channel west of Little Rapids Cut and the others were through three openings in a causeway, which connects the ferry dock with high ground on Sugar Island. Sixty-nine discharge measurements were made on the Little Rapids Section between June 18 and July 31, 1935.

The Garden River Section, located on the Lake George Channel just below the mouth of the Garden River, was 520 feet wide with a maximum depth of 34 feet. The section was divided into five panels. Between July 10 and August 2, 1935, 21 discharge measurements were made.

The locations of these discharge measurement sections are shown on Figure 3-8, except for the Garden River Section, which is shown on Figure 3-9.

3.8.3 Measurement Techniques.

All of the sections were sounded, panels determined and areas computed. The velocity measurements were made using Haskell, Hoff and Gettner velocity meters. Staff gauges were used as section gauges and levels were also measured by various board and self-registering gauges in the head and tailraces of the powerhouses.

Because the Little Rapids and Garden River Sections were new, it was necessary to determine velocity and transverse coefficients. Ten sets of vertical velocity observations were taken at each station. Some were made with two of the compensating works gates open, but the bulk were made with eight gates open. Later, during the discharge measurements for the three and twelve gates open settings, additional vertical velocity runs were made. To clearly define the transverse velocity distribution, the velocity at the 0.4 depth was measured at several points in addition to the index stations. To determine the direction of the current as it crossed the section, paths of floats were observed as they approached and crossed the section.

At the Bingham Ave. Section, the 1909 vertical velocity curve was checked and no change in vertical velocity distribution was noted. A new set of transverse velocity measurements was made.

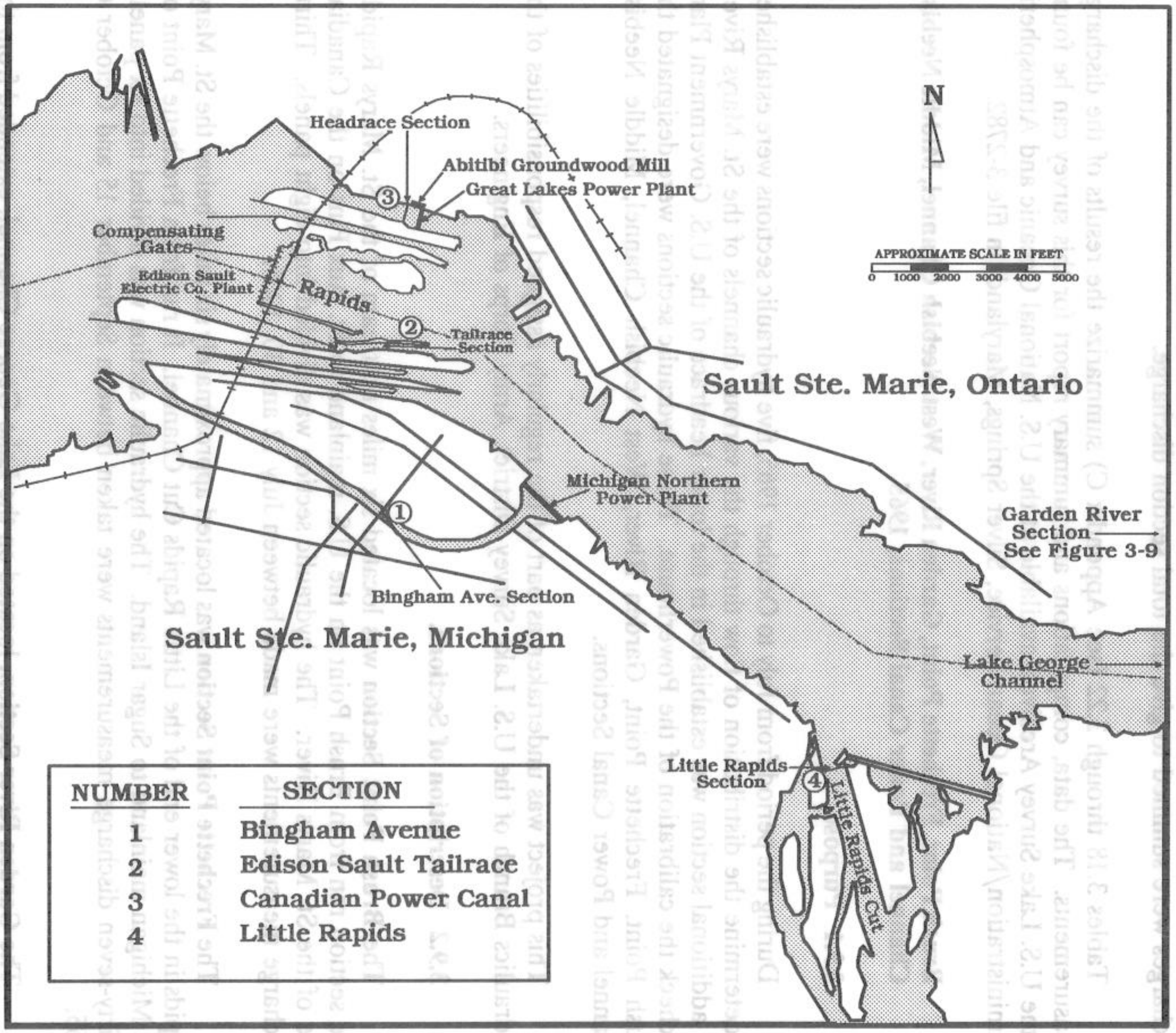
Because the Edison Sault Tailrace Section was also newly established, vertical and transverse velocity measurements were made at each index point.

Although the Canadian Power Canal Section had been metered before, new vertical and transverse velocity measurements were made. Because of the irregularity of the velocity distribution, transverse velocity measurements were made at 12 points across the section.

The discharge measurements gathered at all the sections were made at the panel index points, at the 0.4 depth, using three different meters.

3.8.4 Discharge Computation.

The discharge measurements at all the sections were reduced in a similar manner. The vertical and transverse coefficients were both determined from plots of the average vertical and transverse velocities measured. For each panel, the vertical, transverse and



St. Marys River, 1935 Section Locations

Figure 3-8

directional coefficients for that panel were combined into station coefficients expressing the relationship between the mean panel velocity and the velocity at the panel index point. The velocities measured at the panel points during the discharge measurements were multiplied by the section coefficient and the area of the panel, adjusted for the water elevation at the time of measurement, to get the panel discharge. For each measurement, the panel discharges were summed to give the total section discharge.

Tables 3.18 through 3.22 (see Appendix C) summarize the results of the discharge measurements. The data, computations and summary report for this survey can be found in the U.S. Lake Survey Archives, available at the U.S. National Oceanic and Atmospheric Administration/National Ocean Service, Silver Springs, Maryland, in file 3-2782.

3.9 Brush Point, Frechette Point, Garden River, West Neebish Channel, Middle Neebish Channel and Power Canal Sections, 1965.

3.9.1 Purpose.

During the period from July to October 1965, five hydraulic sections were established to determine the distribution of flow through the various channels of the St. Marys River. An additional section was established in the lower headrace of the U.S. Government Plant to check the calibration of the Powerhouse. These hydraulic sections were designated the Brush Point, Frechette Point, Garden River, West Neebish Channel, Middle Neebish Channel and Power Canal Sections.

This project was undertaken as part of the regularly assigned responsibilities of the Hydraulics Branch of the U.S. Lake Survey District, Army Corps of Engineers.

3.9.2 Description of Sections.

The **Brush Point Section** was located six miles upstream of the St. Marys Rapids. The section ran from Brush Point on the U.S. mainland to Pt. Aux Pins on the Canadian side of the St. Marys River. The hydraulic section was divided into eight panels. Thirty discharge measurements were made between July 12 and 30, 1965.

The **Frechette Point Section** was located approximately six miles below the St. Marys Rapids in the lower end of the Little Rapids Cut Channel. It ran from Frechette Point on the Michigan mainland to Sugar Island. The hydraulic section was divided into six panels. Thirty-seven discharge measurements were taken between September 15 and October 6, 1965.

The **Garden River Section,** located on the Lake George Channel, extended from the northeast shore of Sugar Island, Michigan to the Canadian mainland, at a point approximately 2,500 feet downstream of the confluence of the Garden River. The section was divided into five panels. At this section, 32 discharge measurements were made between September 14 and October 5, 1965.

The **West Neebish Channel Section** was located in the lower end of the West Neebish Channel and ran from Neebish Island to the Michigan mainland. The section was divided into five panels. Thirty-seven discharge measurements were taken between August 20 and September 7, 1965.

The **Middle Neebish Channel Section** was located in the Middle Neebish Channel and extended from Neebish Island to Sugar Island. The section was divided into five panels. Thirty-seven discharge measurements were taken between August 19 and September 8, 1965.

The **U.S. Power Canal Section** was located on the U.S. Power Canal at Sault Ste. Marie, Michigan. It ran from the Vidal Shoals rear range light on the north dike, about 1250 feet above the U.S. Government Powerhouse, perpendicularly across the lower headrace to the center dike. The section was divided into four panels. Ten discharge measurements were made between September 2 and 16, 1965.

The locations of these discharge measurement sections are shown on Figure 3-9, except for the U.S. Power Canal Section, which is shown on Figure 3-10.

3.9.3 Measurement Techniques.

Each section was sounded by lead line, with the positioning determined by transit intersection. Water levels determined during the soundings, by readings from either an automatic or board gauge located near the section, were used to reduce the soundings to a common datum. Soundings were plotted to develop profiles from which subsequent panel areas were determined.

In the U.S. Power Canal Section, a single current meter was suspended from a small boat. The 0.2, 0.4 and 0.8 depth water velocities were measured for periods of from two to three minutes. For the discharge measurements at the remaining sections, a catamaran was positioned over the measuring station at the panels using shore located range targets. The catamaran was equipped to allow three Price type current meters to be suspended in the water simultaneously, giving velocity measurements concurrently at varying depths. One meter was set at the 0.2 depth, another at the 0.4 and the deepest at 0.8 of the sounded depth. Each measurement consisted of simultaneous four-minute observations.

The directions of flow past the hydraulic section at Brush Point, Garden River and Middle Neebish were ascertained by placing floats in the river above the section and tracing them by transit intersection as they drifted with the current across the section lines. The floats, sections of wood 2 inches by 2 inches and ranging in length from 6 to 16 feet, were weighted at one end to maintain an upright positions in the water. The size of the float was dependent upon channel depth, and only a small portion was allowed out of the water to

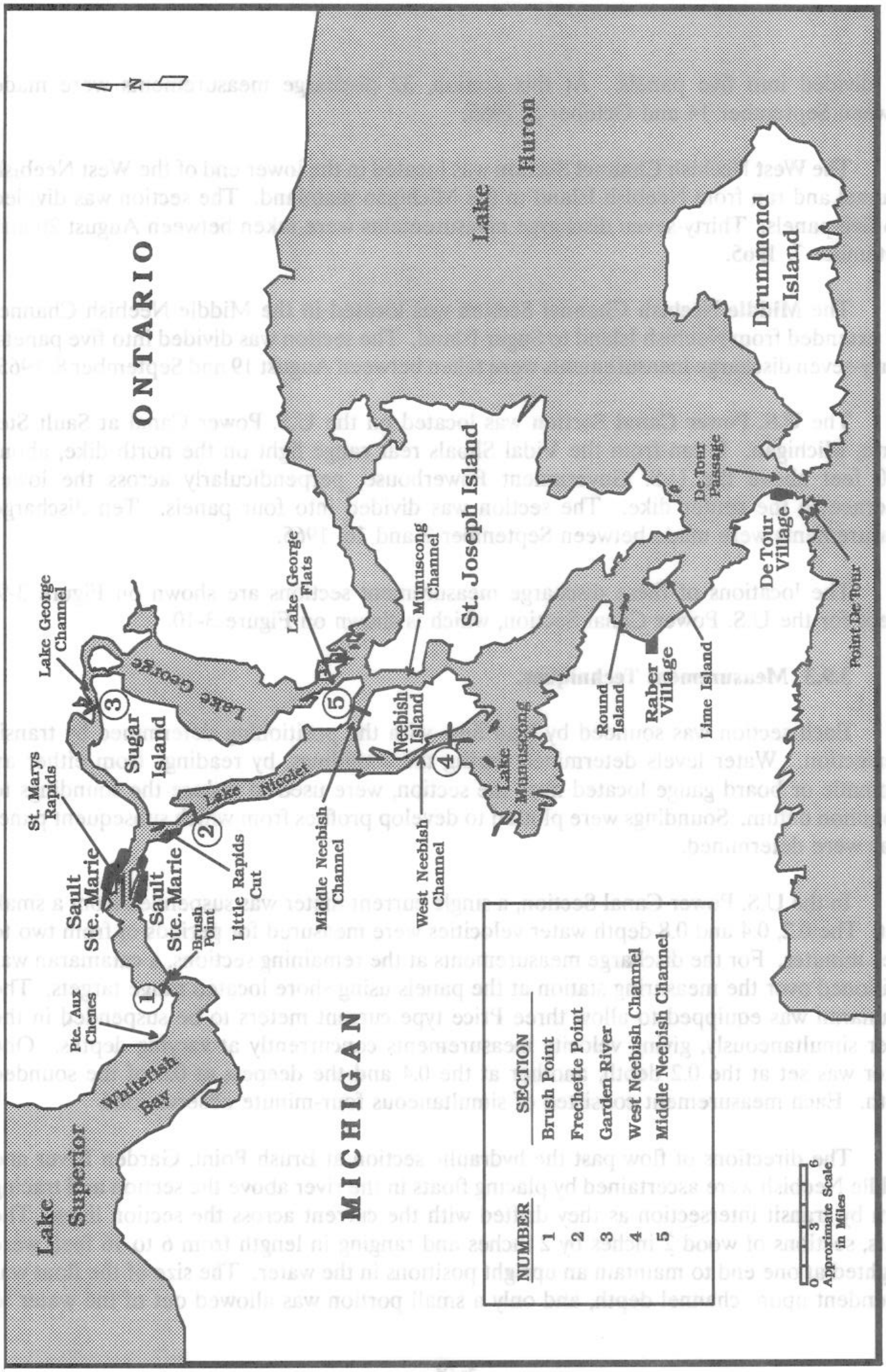

St. Marys River, 1965 Section Locations
ONTARIO
MICHIGAN
Lake Superior
Whitefish Bay
Pte. Aux Chenes
Brush Point
Sault Ste. Marie
Sault Ste. Marie
St. Marys Rapids
Little Rapids Cut
Sugar Island
Lake George Channel
Lake George
Lake Nicolet
Middle Neebish Channel
West Neebish Channel
Neebish Island
Lake George Flats
Munuscong Channel
St Joseph Island
Lake Munuscong
Round Island
Raber Village
Lime Island
De Tour Passage
De Tour Village
Point De Tour
Drummond Island
Lake Huron
N
NUMBER SECTION
1 Brush Point
2 Frechette Point
3 Garden River
4 West Neebish Channel
5 Middle Neebish Channel
0 3 6
Approximate Scale in Miles

Figure 3-9

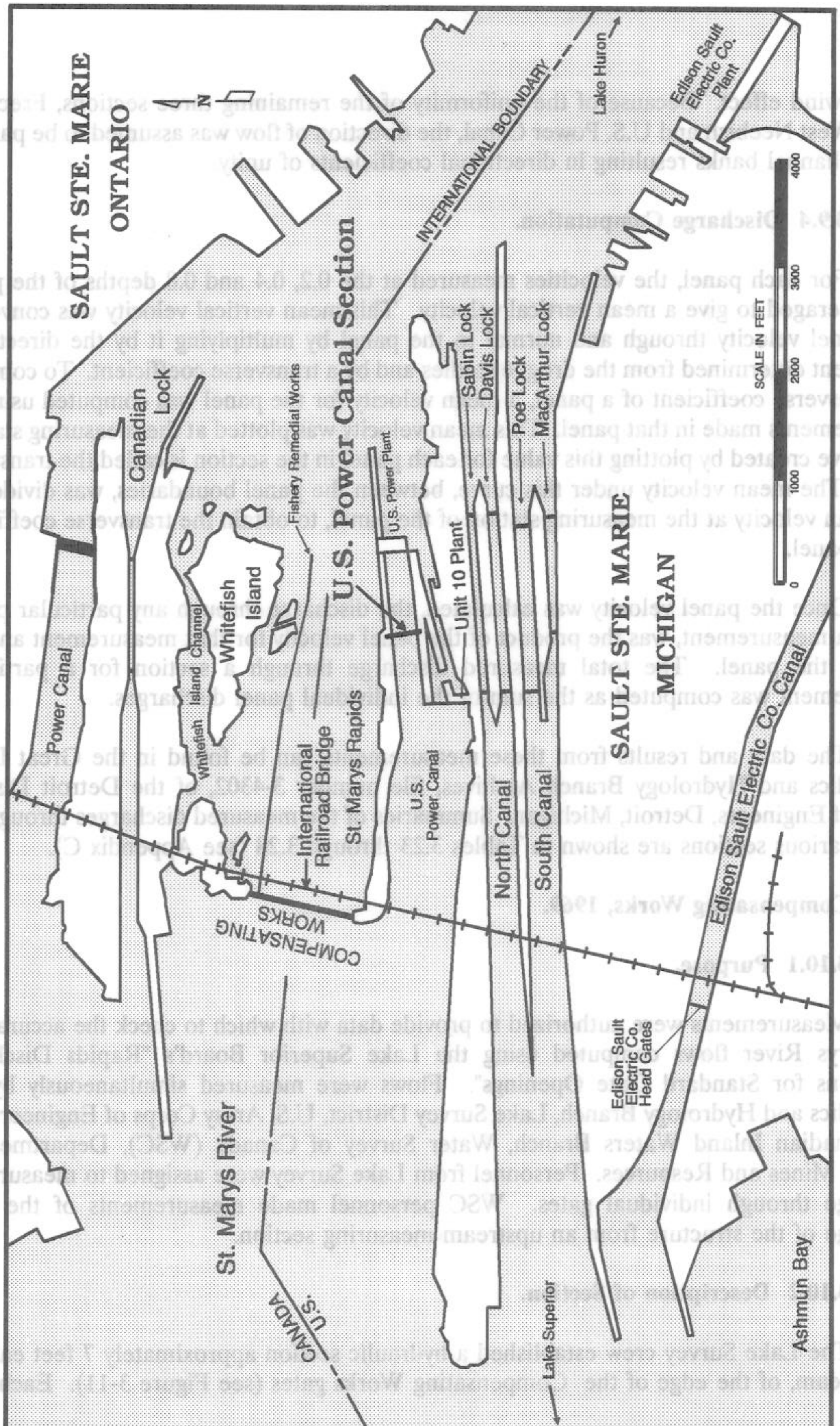

St. Marys River, U.S. Power Canal Section
SAULT STE. MARIE
ONTARIO
SAULT STE. MARIE
MICHIGAN
U.S. Power Canal Section
INTERNATIONAL BOUNDARY
Lake Huron
Lake Superior
Edison Sault Electric Co. Plant
Power Canal
Canadian Lock
Fishery Remedial Works
Whitefish Island
Whitefish Island Channel
U.S. Power Plant
Unit 10 Plant
Sabin Lock
Davis Lock
Poe Lock
MacArthur Lock
International Railroad Bridge
St. Marys Rapids
U.S. Power Canal
North Canal
South Canal
Edison Sault Electric Co. Canal
COMPENSATING WORKS
St. Marys River
Edison Sault Electric Co. Head Gates
Ashmun Bay
CANADA
U.S.
SCALE IN FEET
0
1000
2000
3000
4000
N

Figure 3-10

reduce wind effect. Because of the uniformity of the remaining three sections, Frechette Point, West Neebish and U.S. Power Canal, the direction of flow was assumed to be parallel to the channel banks resulting in directional coefficients of unity.

3.9.4 Discharge Computation.

For each panel, the velocities measured at the 0.2, 0.4 and 0.8 depths of the panel were averaged to give a mean vertical velocity. This mean vertical velocity was converted to a panel velocity through and normal to the panel by multiplying it by the directional coefficient determined from the drogue studies and by a transverse coefficient. To compute the transverse coefficient of a panel, a mean velocity for the panel was computed using all measurements made in that panel. This mean velocity was plotted at the measuring station. The curve created by plotting this value for each panel in the section is called the transverse curve. The mean velocity under this curve, between the panel boundaries, was divided by the mean velocity at the measuring station of the panel, to obtain the transverse coefficient of the panel.

Once the panel velocity was calculated, the discharge through any particular panel, during a measurement, was the product of the panel velocity for that measurement and the area of the panel. The total measured discharge through a section for a particular measurement was computed as the sum of the individual panel discharges.

The data and results from these measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number 3-4302, of the Detroit District, Corps of Engineers, Detroit, Michigan. Summaries of the measured discharges through the above various sections are shown in Tables 3.23 through 3.28 (see Appendix C).

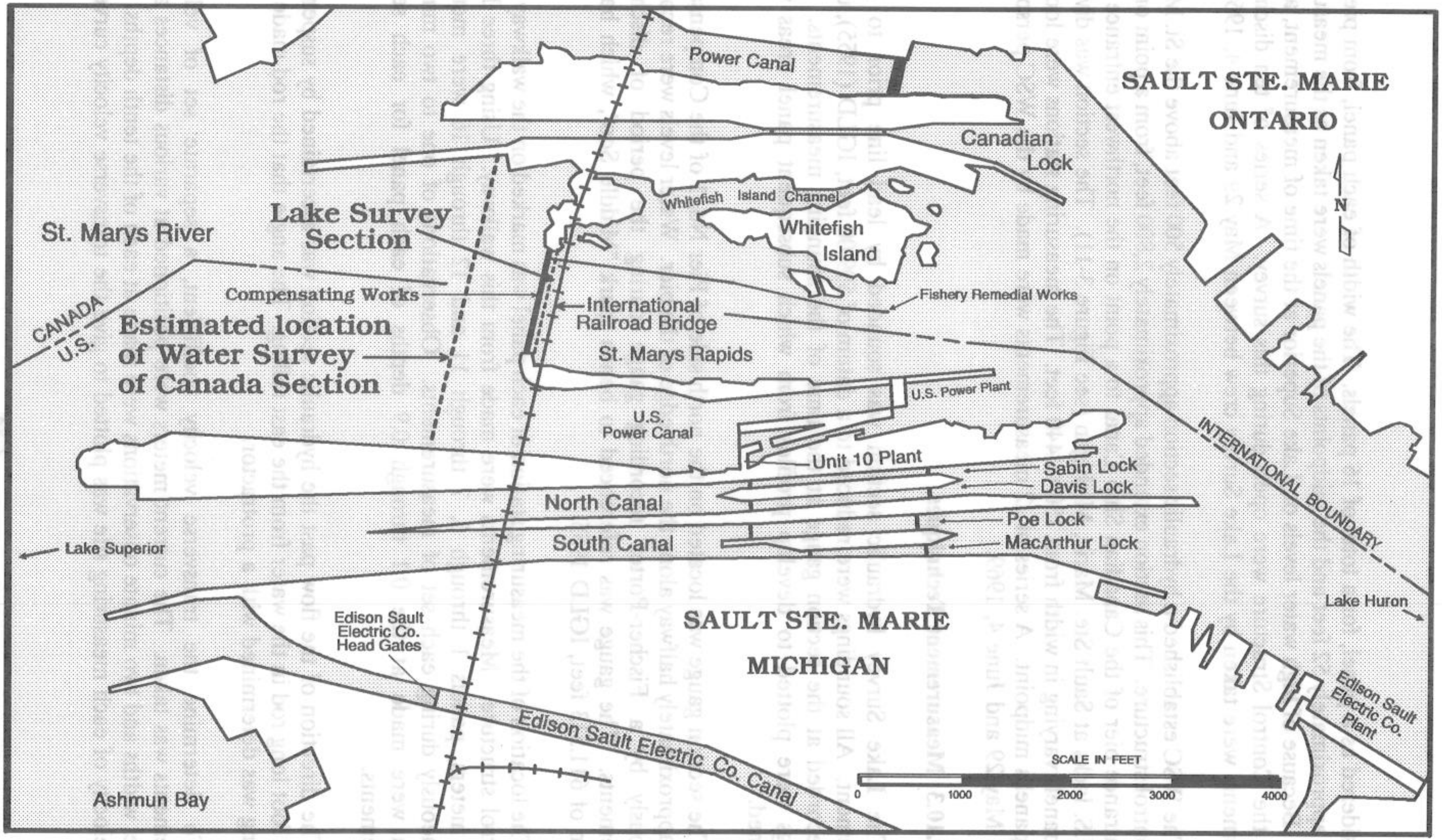
3.10 Compensating Works, 1969.

3.10.1 Purpose.

Measurements were authorized to provide data with which to check the accuracy of St. Marys River flows computed using the Lake Superior Board's "Rapids Discharge Equations for Standard Gate Openings". Flows were measured simultaneously by the Hydraulics and Hydrology Branch, Lake Survey District, U.S. Army Corps of Engineers and the Canadian Inland Waters Branch, Water Survey of Canada (WSC), Department of Energy, Mines and Resources. Personnel from Lake Survey were assigned to measure the discharge through individual gates. WSC personnel made measurements of the total discharge of the structure from an upstream measuring section.

3.10.2 Description of Section.

The Lake Survey crew established a hydraulic section approximately 7 feet east, or downstream, of the edge of the Compensating Works gates (see Figure 3-11). Each gate



St. Marys River, Compensating Works, 1969 Section Locations

Figure 3-11

was considered as a panel, for a total of 16 panels. The width of each panel, from pier to pier was approximately 52 feet and the midpoints of the panels were taken as the measuring stations. Because of high water levels on Lake Superior at the time of measurement, all 16 gates in the Control Structure were open during this survey. A series of ten discharge measurements were taken by the Lake Survey crew between May 29 and June 4, 1969.

The WSC established a hydraulic section approximately 500 feet above the St. Marys River control structure. This section extended approximately 2,800 feet, from a point on the south entrance pier of the Canadian Ship Canal to a point on the northwest entrance pier to the U.S. locks at Sault Ste. Marie, Michigan (see Figure 3-11). The section was divided into 13 panels varying in width from 150 to 440 feet. The measuring stations were located at each panel's midpoint. A series of 12 measurements were made by the WSC personnel between May 29 and June 4, 1969.

3.10.3 Measurement Techniques.

The Lake Survey hydraulic section was sounded by lead line prior to each measurement. All soundings were reduced to a datum of 599.00 feet, IGLD (1955), using levels recorded at the section gauge at the time of the sounding measurements. The soundings were plotted to develop profiles from which subsequent panel areas were determined.

The section gauge was located on the north side of Pier No. 1 of the Compensating Works, approximately halfway along the north edge of the pier. Water levels were recorded continuously by a Fischer-Porter recording gauge during the period of discharge measurements. The gauge was referenced to bench mark "Middle Soo", which has an elevation of 611.513 feet, IGLD 1955.

The location of the measuring station of each panel was marked on the walkway over the control structure. Measurements were made from this walkway. Using three Price current meters, panels 1 through 6, 7 through 11 and 12 through 16 were metered simultaneously during each set of measurements. Observations of one to two minutes duration were made at the 0.1 through 0.9 depths of each panel for each set of measurements.

The direction of the flow past the hydraulic section was ascertained by suspending an eight foot long rod in the water from the east railing. The angle that the rod made with the railing was determined with a protractor.

To determine the transverse velocity coefficient, a separate set of velocity measurements was taken. The current meters were positioned at various distances along the panel widths and two minute observations were made at each of the tenth depths. The mean velocity of each measuring site was plotted to give the transverse velocity curve.

With respect to the Water Survey of Canada hydraulic section, a direction of flow survey was made on May 24, using a standard aluminum drogue suspended at the 0.6 depth. On May 26, a series of 30 soundings and velocity observations at the 0.6 depth were made as a basis for subdividing the section into panels. The discharge measurements consisted of 2 minute velocity readings at each tenth depth at each panel measuring point using Gurley Price, pattern 622, current meters. Water levels used to reduce the measurements at this section were recorded at the Upper Soo water level gauge, a recording gauge located on the river side of the north entrance pier of the Canadian Ship Canal. The Upper Soo gauge was referenced to bench mark "Middle Soo", elevation noted above.

3.10.4 Discharge Computation.

The procedure used to compute the total section discharge was very similar to that described in Subsection 3.9.4. A summary of the resulting discharges may be found in Tables 3.29 and 3.30 (see Appendix C). The data and results of this survey may be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 71-4, of the Detroit District, U.S. Army Corps of Engineers, Detroit, Michigan.

The measured discharge at the Canadian section included the discharge through the control structure plus the discharge through the U.S. Power Canal. The discharge through the Power Canal, as supplied by the Power Company, was deducted from the measured discharge to give the discharge through the control structure.

3.11 Frechette Point, Garden River, Middle Neebish and West Neebish Sections, 1969.

3.11.1 Purpose.

From September 18 to October 21, 1969, a series of discharge measurements were made at four hydraulic sections on the St. Marys River. These measurements were made to obtain data for computing the amount and distribution of flow through the various channels of the lower St. Marys River, and to provide the necessary data for the development of a mathematical model of the lower river.

3.11.2 Description of Sections.

The **Frechette Point Section,** originally established in 1965, was located in the lower end of the Little Rapids Cut Channel. The section ran from Frechette Point on the Michigan mainland to Sugar Island. The hydraulic section was divided into seven panels. Approximately 320 feet from the Michigan mainland, there was a 50 foot area of dead water, caused by thick weeds growing all the way to the surface. The section gauge for this section was the permanent Stevens recording gauge located at Frechette Point. Twenty discharge measurements were taken at this section between September 18 and 27, 1969, and ten between October 16 and 21, 1969.

The **Garden River Section,** also previously established, extended from the northeast shore of Sugar Island, Michigan, to the Canadian mainland at a point approximately 2,500 feet downstream of the Garden River confluence. This hydraulic section was divided into six panels. The first panel started 22 feet from the north shore. There was approximately 30 feet of dead water off the south shore. The Garden River section gauge was a Fischer-Porter digital recorder, temporarily installed on the shore of Sugar Island, near the section. From September 18 to September 27, 1969, 21 discharge measurements were taken, and from October 16 to October 21, 1969, a series of 11 discharge measurements were made.

The **Middle Neebish Section** was located on the Middle Neebish Channel between Neebish Island and Sugar Island. The section was divided into 6 panels. A Fischer-Porter digital recorder was temporarily installed on Neebish Island near the section. Eighteen discharge measurements were made between October 2 and 13, 1969.

The **West Neebish Section** was located on the lower end of the West Neebish Channel. This section extended from Neebish Island to the Michigan mainland. The hydraulic section was divided into 5 equal panels. Each panel was 60 feet wide, and the measuring point was in the middle of the panel. The section gauge was a temporary Fischer-Porter recorder located near the west end of the section line. Between October 2 and 13, 1969, 40 discharge measurements were taken.

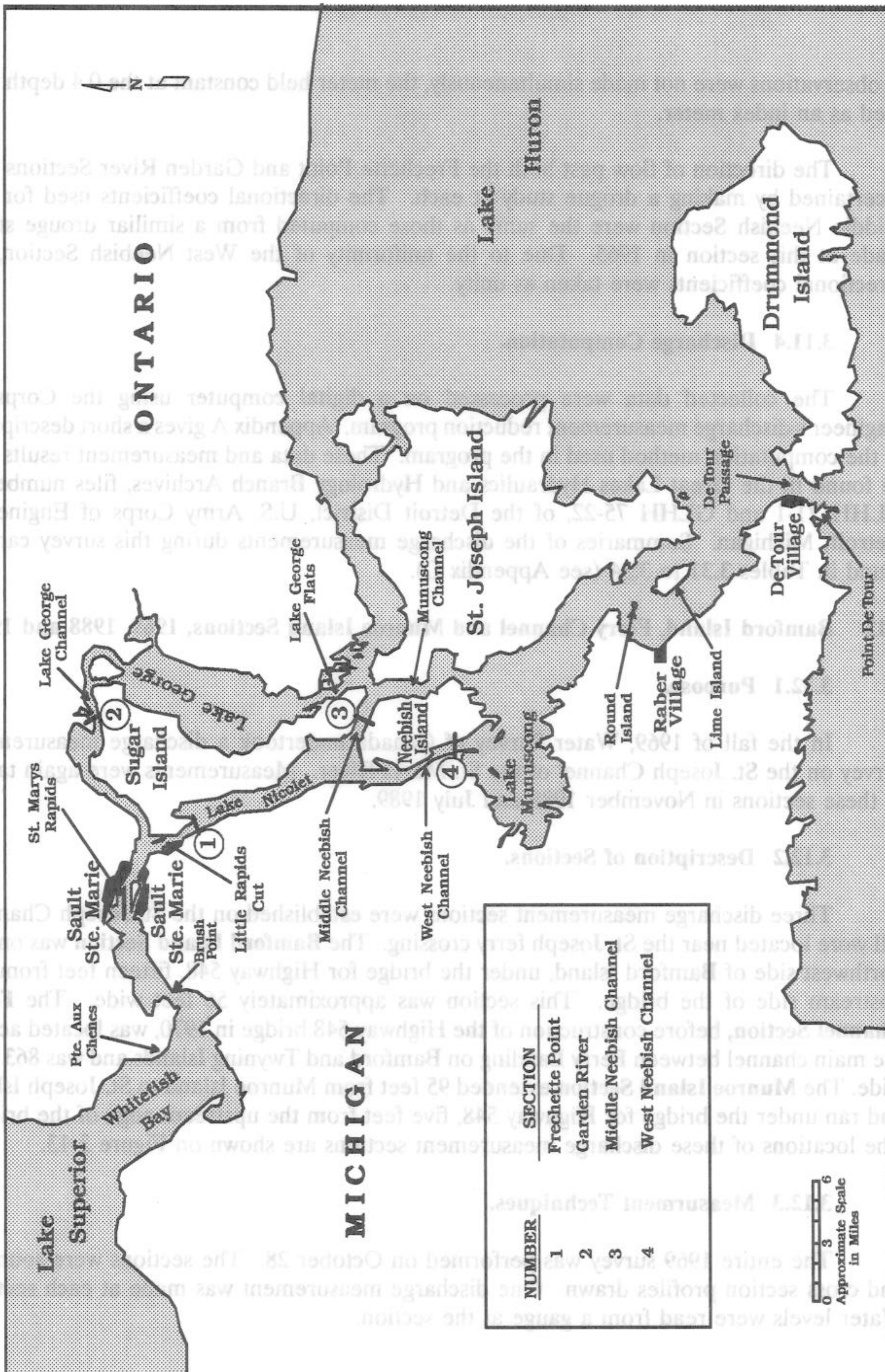
The locations of these discharge measurement sections are shown on Figure 3-12.

3.11.3 Measurement Techniques.

Each of the four sections was sounded by lead line. Positioning on the Frechette Point Section was determined by transit intersection. Positioning on the other three sections was determined by tagline. Readings from either an automatic gauge or a board gauge located near the sections were recorded for the purpose of reducing the soundings to a common datum at each section. The soundings were then plotted to develop profiles. From these profiles, subsequent panel areas were determined.

The Frechette Point and Garden River Sections were measured simultaneously, and the Middle Neebish and West Neebish Sections were also measured simultaneously. This was accomplished by having the U.S. Lake Survey's Catamaran No. 4 and Catamaran No. 5 measure different sections at the same time.

Each measurement consisted of three sets of four-minute observations at each panel. Four Price current meters were used for each set of observations. Three meters were put at varying depths and the fourth meter was held constant at the 0.4 depth. During the first set of observations, meters were placed at the 0.1, 0.4, 0.7 and 0.4 depths, and a four-minute observation was made for each meter, simultaneously. Similarly for the second set of observations, the meters were placed at the 0.3, 0.6, 0.9, and 0.4 depths. Since all three sets



St. Marys River, 1969 Section Locations

Figure 3-12

of observations were not made simultaneously, the meter held constant at the 0.4 depth was used as an index meter.

The direction of flow past both the Frechette Point and Garden River Sections was ascertained by making a drogue study at each. The directional coefficients used for the Middle Neebish Section were the same as those computed from a similiar drouge study made at this section in 1965. Due to the uniformity of the West Neebish Section, its directional coefficients were taken as unity.

3.11.4 Discharge Computation.

The collected data were processed on a digital computer using the Corps of Engineer's discharge measurement reduction program. Appendix A gives a short description of the computation method used in the program. These data and measurement results can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, files numbered GLHH 71-1 and GLHH 75-22, of the Detroit District, U.S. Army Corps of Engineers, Detroit, Michigan. Summaries of the discharge measurements during this survey can be found in Tables 3.31 to 3.34 (see Appendix C).

3.12 Bamford Island, Ferry Channel and Munroe Island Sections, 1969, 1988 and 1989.

3.12.1 Purpose.

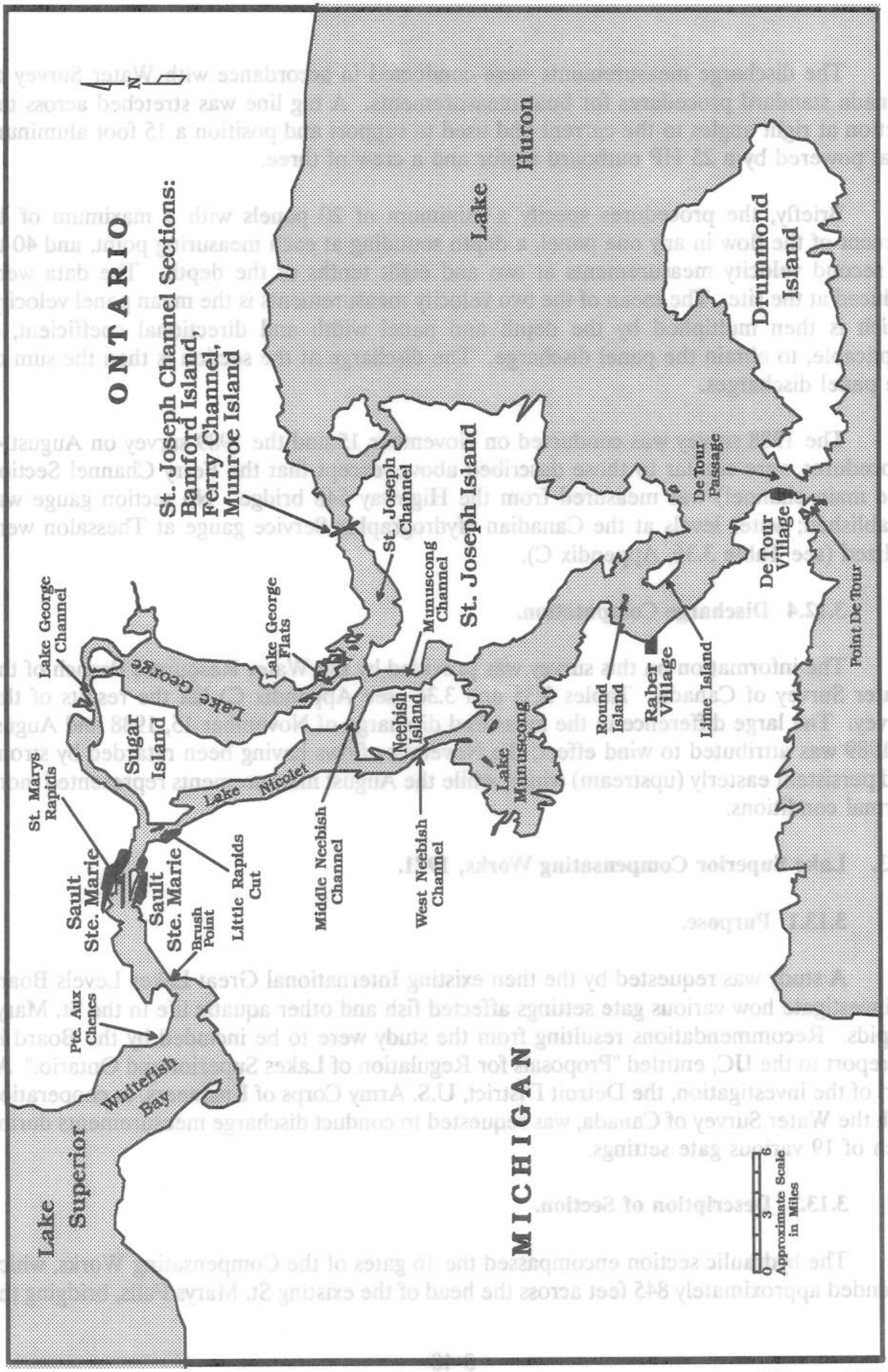
In the fall of 1969, Water Survey of Canada undertook a discharge measurement survey on the St. Joseph Channel of the St. Marys River. Measurements were again taken at these sections in November 1988 and July 1989.

3.12.2 Description of Sections.

Three discharge measurement sections were established on the St. Joseph Channel. All were located near the St. Joseph ferry crossing. The **Bamford Island Section** was on the northwest side of Bamford Island, under the bridge for Highway 548, fifteen feet from the upstream side of the bridge. This section was approximately 56 feet wide. The **Ferry Channel Section,** before construction of the Highway 548 bridge in 1970, was located across the main channel between Ferry Landing on Bamford and Twyning Islands and was 863 feet wide. The **Munroe Island Section** extended 95 feet from Munroe Island to St. Joseph Island and ran under the bridge for Highway 548, five feet from the upstream edge of the bridge. The locations of these discharge measurement sections are shown on Figure 3-13.

3.12.3 Measurment Techniques.

The entire 1969 survey was performed on October 28. The sections were sounded and cross section profiles drawn. One discharge measurement was made at each section. Water levels were read from a gauge at the section.



St. Marys River, St. Joseph Channel Section Locations
ONTARIO
MICHIGAN
St. Joseph Channel Sections:
Bamford Island,
Ferry Channel,
Munroe Island
N
Lake Superior
Whitefish Bay
Pte. Aux Chenes
Brush Point
Sault Ste. Marie
Sault Ste. Marie
St. Marys Rapids
Little Rapids Cut
Sugar Island
Lake Nicolet
Lake George
Lake George Channel
Lake George Flats
Middle Neebish Channel
Neebish Island
West Neebish Channel
Lake Munuscong
Munuscong Channel
St. Joseph Channel
St. Joseph Island
Round Island
Raber Village
Lime Island
De Tour Village
De Tour Passage
Point De Tour
Drummond Island
Lake Huron
0 3 6
Approximate Scale in Miles

Figure 3-13

The discharge measurements were conducted in accordance with Water Survey of Canada standard procedures for boat measurements. A tag line was stretched across the section at right angles to the current and used to support and position a 15 foot aluminum boat powered by a 25 HP outboard motor and a crew of three.

Briefly, the procedures specify a minimum of 20 panels with a maximum of 10 percent of the flow in any one panel, a depth sounding at each measuring point, and 40 to 70 second velocity measurements at two and eight tenths of the depth. The data were reduced at the site. The mean of the two velocity measurements is the mean panel velocity, which is then multiplied by the depth and panel width and directional coefficient, if applicable, to obtain the panel discharge. The discharge at the section is then the sum of the panel discharges.

The 1988 survey was conducted on November 15 and the 1989 survey on August 4. Procedures were similar to those described above, except that the Ferry Channel Section (the main channel) was measured from the Highway 548 bridge. No section gauge was established; water levels at the Canadian Hydrographic Service gauge at Thessalon were utilized (see Table 3.36, Appendix C).

3.12.4 Discharge Computation.

The information on this survey was provided by the Water Resources Branch of the Water Survey of Canada. Tables 3.35 and 3.36 (see Appendix C) list the results of this survey. The large difference in the measured discharge of November 15, 1988 and August 4, 1989 was attributed to wind effect; the November flows having been retarded by strong and persistent easterly (upstream) winds, while the August measurements represented more normal conditions.

3.13. Lake Superior Compensating Works, 1971.

3.13.1 Purpose.

A study was requested by the then existing International Great Lakes Levels Board to investigate how various gate settings affected fish and other aquatic life in the St. Marys Rapids. Recommendations resulting from the study were to be included by the Board in its report to the IJC, entitled "Proposals for Regulation of Lakes Superior and Ontario." As part of the investigation, the Detroit District, U.S. Army Corps of Engineers, in cooperation with the Water Survey of Canada, was requested to conduct discharge measurements during each of 19 various gate settings.

3.13.2 Description of Section.

The hydraulic section encompassed the 16 gates of the Compensating Works, which extended approximately 845 feet across the head of the existing St. Marys Falls, bridging the

International Boundary between Canada and the United States (see Figure 3-11 for section location). Each gate opening is approximately 52 feet in width. Gates 1 through 8 are on the Canadian side; gate 9 is cut by the International Boundary, but maintained by the U.S., as are gates 10 through 16.

3.13.3 Measurement Techniques.

Between July 23 and August 16, 1971, flow measurements were accomplished at each of the 16 gates, under various gate settings. The discharge measurements were made using Price current meters. Meters were suspended over the upstream railing of the structure and velocities were measured on the plane upstream of the control gates. A cable was stretched under the caps of the structure piers on the upstream end to prevent the meters from being carried downstream under the gates.

Headwater stages, during the tests, were recorded at the Upper Soo gauge; an automatic analog water level recorder, located about halfway down the southwest Canadian Canal dike. Since there was a variation in the water surface from gate to gate, due to the influence of closed gates, the stage at each gate, during the measurements, was determined by measuring down to the water surface from temporary bench marks established on the upstream railing of each gate. Water levels were also recorded downstream of the section at the Control Structure Tailrace gauge; a staff gauge placed on the Canadian end of the tailrace wingwall.

Before the first of the gate movements were made for the test, transverse curves were determined across eight of the control gates. This was done by measuring the velocity at the 0.6 depth at the gate centerline, and at 2 foot depth intervals out to 10 feet from each pier. Measurements were taken four times at each of the eight gates.

After the movement of gates was initiated on July 26, 1971, it was necessary to measure the complete flow through the control structure in the time between the various gate settings. With limited time available for a complete measurement of the entire structure, an abbreviated measuring technique had to be employed. Transverse curves were determined in the manner described above for those gates that were most affected by gate movements. When a gate was closed, it was felt that the closure would most affect the transverse flow distribution of the adjacent open gates. At the other gates, when the transverse flow distribution was not significantly affected by the most recent gate movements, only the centerline velocity was measured. A vertical velocity profile was determined for each of the gate centers by measuring velocities at each tenth of depth.

During the periods when only four gates at most had to be measured, more time was available to make discharge measurements. For these gate settings, five vertical velocity profiles were measured at each gate. These profiles were measured at the gate centerline and at 6 feet and 16 feet from each pier. The velocity was measured for each of the five profiles at each tenth of depth. This particular method of discharge measurement was found to be superior to the three point method initially used to obtain the transverse distribution of flow at the various gates.

3.13.4 Discharge Computation.

Transverse velocity curves were determined for eight gates prior to the actual discharge measurements by sampling the transverse velocity, as previously described. The transverse velocity measurements within a panel were averaged and plotted to form a transverse velocity curve for that panel. The average transverse velocity in a panel was determined by computing the mean velocity across the transverse velocity curve. The transverse velocity coefficient was then determined by dividing the average transverse velocity by the centerpoint velocity. This coefficient was used with the discharge measurements, where time only allowed for measuring velocity at the gate centerpoints.

When time was most limited and discharges through the gates had to be determined by a single centerpoint velocity measurement, the centerpoint velocities were plotted to show the vertical velocity distribution. A smooth curve was drawn through the nine vertical velocity points. The arithmetic mean of the nine-tenth depth velocities taken from the smooth curve was used as the average centerpoint velocity. A von Karman equation was not used nor was planimetering used in the determination of the average velocity in the vertical. This was due to the great number of vertical velocity determinations that had to be made manually and the unusual shape of some of the vertical velocity curves.

Another method used to determine transverse curves, during periods when four gates or less were measured, involved measuring five vertical velocity profiles transversely across the gate. The data gathered from this method was first plotted to get vertical velocity profiles. The average vertical velocity was computed as the arithmetic mean of the nine-tenth depths taken from the best smooth curve through the actual velocity measurements. The five average vertical velocities, having been determined, were plotted to define the transverse velocity curve. The average transverse velocity was then determined by taking the mean of the smooth transverse curve through the five velocity points.

Throughout the test, transverse velocities were measured at gates where it was thought that a change in flow distribution would result from gate setting changes. Transverse velocity coefficients from the most appropriate gate setting were used in determining gate discharge.

The gate discharge was computed by multiplying the gate cross-sectional area by: 1) the average centerpoint velocity and the transverse velocity coefficient; or 2) the mean transverse velocity.

The data and results of this series of measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 73-4, of the Detroit District, Corps of Engineers, Detroit, Michigan. Table 3.37 summaries the gate discharges, and

Table 3.38 gives the daily mean water levels recorded at the Upper Soo gauge and the Tailrace gauge, during the period of discharge measurements (see Appendix C).

3.14. Frechette Point and Garden River Sections, 1971-1972.

3.14.1 Purpose.

This survey was conducted to determine the effect a natural ice cover has on St. Marys River flows around Sugar Island. The Frechette Point and Garden River Sections were to be metered concurrently, both under ice free and ice covered conditions. Ice free measurements were made on both sections between December 11 and 15, 1971. Measurements during ice covered conditions were only made on the Frechette Point Section. At the time of these measurements, February 4-8, 1972, there was an incomplete ice cover at the Garden River Section.

3.14.2 Description of Sections.

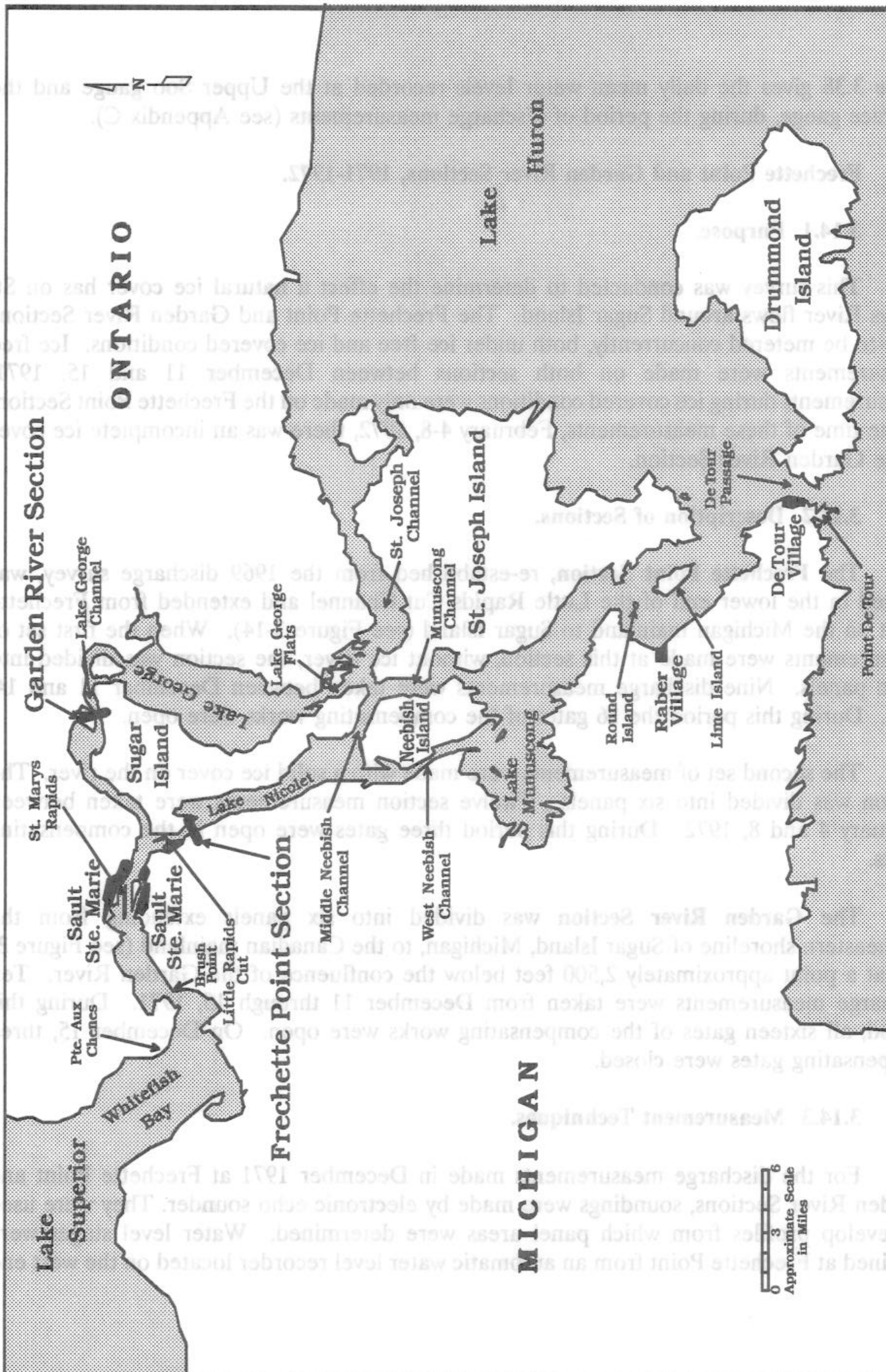
The **Frechette Point Section,** re-established from the 1969 discharge survey, was located in the lower end of the Little Rapids Cut Channel and extended from Frechette Point on the Michigan mainland to Sugar Island (see Figure 3-14). When the first set of measurements were made at this section, without ice cover, the section was divided into seven panels. Nine discharge measurements were taken between December 11 and 14, 1971. During this period the 16 gates of the compensating works were open.

The second set of measurements were made with a solid ice cover on the river. The section was divided into six panels. Twelve section measurements were taken between February 4 and 8, 1972. During this period three gates were open in the compensating works.

The **Garden River Section** was divided into six panels extending from the northeastern shoreline of Sugar Island, Michigan, to the Canadian mainland (see Figure 3-14), at a point approximately 2,500 feet below the confluence of the Garden River. Ten discharge measurements were taken from December 11 through 15, 1971. During this period, all sixteen gates of the compensating works were open. On December 15, three compensating gates were closed.

3.14.3 Measurement Techniques.

For the discharge measurements made in December 1971 at Frechette Point and Garden River Sections, soundings were made by electronic echo sounder. They were used to develop profiles from which panel areas were determined. Water level stages were obtained at Frechette Point from an automatic water level recorder located on the west end



St. Marys River, Frechette Point and Garden River Section Locations

Figure 3-14

of the section. A temporary automatic digital water level gauge was installed on the shore of Sugar Island near the Garden River Section line to obtain water level stages at that section.

Discharge measurements were made concurrently on the Garden River and Frechette Point Sections. Each measurement consisted of two-minute observations of velocity using three Price current meters placed initially at the 0.3, 0.6 and 0.9 depths and subsequently raised by 0.1 increments to cover the remaining tenth depths. A fourth meter was held constant at the 0.4 depth as an index meter.

When measurements were taken at the Frechette Point Section, in February 1972, holes were drilled through the ice cover to allow for meters to be lowered into the water. Flow measurements were made in a manner similar to those made in December 1971, as described above. Soundings were obtained by spot-checking, with a lead line, the soundings previously made in December.

3.14.4 Discharge Computation.

The data collected were keypunched and then processed on a digital computer, using the Detroit District, Corps of Engineers' discharge measurement reduction program. This program is briefly described in Appendix A. The data and results of these measurements and computations can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 72-10, of the Detroit District, Corps of Engineers, Detroit, Michigan. Tables 3.39-3.41 summarize the measured discharges (see Appendix C).

3.15 Frechette Point and Garden River Sections, 1973.

3.15.1 Purpose.

The purpose of this survey was to determine the effect an ice cover has on the flow velocity distribution around Sugar Island, which in turn may affect ship navigation and the efficiency with which the channels pass ice. A series of river flow measurements were taken simultaneously in the Little Rapids Cut Channel and the North Lake George Channel. This was the first time discharge measurements were made concurrently in both channels under condition of complete ice cover.

3.15.2 Description of Sections.

The **Frechette Point Section,** originally established in 1965 and re-established in 1969, 1971 and 1972, was located at the lower end of the Little Rapids Cut Channel (see Figure 3-14). The hydraulic section was divided into seven panels, from east to west. Seventeen sets of measurements were made, concurrent with measurements made at the Garden River Section, between February 17 and 21, 1973. At the time of the survey, the ice cover at this section was 12 to 24 inches thick.

The **Garden River Section,** recovered from previous discharge measurement surveys, was located on the Lake George Channel of the St. Marys River, about a half mile downstream of the mouth of the Garden River (see Figure 3-14). The hydraulic section was divided into six panels extending from the Canadian mainland to Sugar Island, Michigan. The first panel began 32 feet out from the Canadian shore, due to thick ice near the shore. Between the sixth panel and the water's edge, there was a 49 foot wide area considered dead water, due to thick ice near the shore. At the time measurements were made, most of the Garden River Section was covered by about 18 inches of ice.

3.15.3 Measurement Techniques.

At the time of this survey, 1-1/2 gates of the compensating works were open, resulting in a total river flow of about 55,000 cfs. This is the minimum winter flow allowed under the regulation plan governing Lake Superior outflow. This low flow allowed many reaches of the channels to freeze over sufficiently for measurements to be safely taken. These winter flow measurements were conducted with methods similar to those used during the open water measurements, with the exception that the ice thickness and the effective area of flow had to be determined prior to measuring. The effective area of flow across the section was determined by lowering a meter through the ice until a velocity was first detected and a sounding was taken from that elevation. Under a smooth ice cover, this was located just below the bottom ice surface. Under broken ice, it varied up to three feet below the ice surface, depending on the amount of ice layering and roughness.

After being spot sounded for comparison to the original soundings, the section profiles from the 1969 survey were adjusted to new water surface elevations based upon the effective area of flow. These adjusted profiles were used to determine panel areas.

Water surface elevations near each section were periodically monitored during the period of measurement. At the Frechette Point Section water levels were monitored using the Frechette gauge, a permanent water level recording gauge owned and maintained by NOAA. This gauge was located approximately 1,500 feet upstream of the section. At the Garden River Section, a board gauge located approximately 500 feet upstream of the section was used.

Flow measurements were conducted using three ice sleds at each section. The sleds were equipped with a meter, meter winch, batteries and a counter to record the revolutions of a Price current meter. The meters were lowered through holes cut in the ice at each panel measuring point. Metering point locations were established by chaining off the respective distances from the onshore horizontal control stations. Current velocities were measured for two minutes at each tenth of the effective depth for each panel. Three panels could be metered at a time on both sections. Measurements were made at the Frechette Point and Garden River Sections simultaneously.

3.15.4 Discharge Computation.

The data collected were reduced using the Detroit District, Corps of Engineers' discharge measurement program. A brief description of the methods used in this program is given in Appendix A. A summary of the results of the measurements at the two sections is given in Tables 3.42 and 3.43 (see Appendix C).

The data and results of these measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 73-17, of the Detroit District, Corps of Engineers, Detroit, Michigan.

3.16 Lake Superior Compensating Works, 1974.

3.16.1 Purpose.

In a February 2, 1974 memorandum to the International Lake Superior Board of Control, the River Flow Subcommittee of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data requested a check on the calibration of the Compensating Works. In order to measure the total range of flows to be expected through the Compensating Works, it was proposed to have up to sixteen gates opened. Due to high water levels on the lower St. Marys River, during the measurement period, the Lake Superior Board was unable to comply with more than ten gates open.

The discharge measurements, made between June 13 and 27, 1974, were a joint effort by the Great Lakes Hydraulics and Hydrology Branch of the Detroit District, Corps of Engineers and the Water Survey of Canada, Department of Environment.

3.16.2 Description of Section.

The hydraulic section encompassed the 16 gates of the Compensating Works structure, which extends approximately 845 feet across the head of the existing St. Marys Rapids; bridging the International Boundary between Canada and the United States. See Figure 3-11 for the Compensating Works location. Gates numbered 1 through 8 are on the Canadian side. Gate number 9 is cut by the International Boundary line, but is maintained by the United States, as are gates 10 through 16. Each gate is approximately 52 feet in width. Measurements were taken on the upstream side of each open gate.

3.16.3 Measurement Techniques.

Between June 13 and 27, 1974, forty sets of discharge measurements were made. Five panels per open gate were measured; measuring stations being at 6 feet and 16 feet out from (perpendicular to) each pier and at the gate centerline. A water surface profile was obtained across each gate by measuring down from a known elevation along the walkway above the structure. Also, a sounding depth was obtained at each gate setting. The discharge measurements were made using Price current meters suspended on 100-pound sounding weights. Meters were suspended over the control structure railings; velocities were measured upstream of the control gates. Up to four gates were metered simultaneously. Meter readings of one to two minutes were made at each tenth of the effective depth for each panel. Mean water surface elevations were determined at the Southwest Pier gauge.

3.16.4 Discharge Computation.

Cross-sectional profiles were prepared for each gate for each series of gate settings. For each gate setting, vertical velocity profiles were plotted at each metering location across the open gates. Average vertical velocities at each meter location were used to plot a horizontal velocity profile of the gate at a particular gate setting. The average velocity from this profile was multiplied by the cross section area, adjusted for the prevailing water level, to obtain the discharge through the gate for each pertinent gate setting.

The results of these measurements can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 74-8A-C, of the Detroit Districts, Corps of Engineers, Detroit, Michigan. Table 3.44 summarizes the results of the measurements (see Appendix C).

3.17 U.S. Power Canal, Fort Street Bridge, Upper Gate, Upper Headrace, Lower Headrace and Groundwood Mill Tailrace Sections, 1975.

3.17.1 Purpose.

At the request of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, simultaneous discharge measurements were made in the Edison Soo power canal, the U.S. Powerhouse canal, the Canadian power canal and at a section established above the compensating gates. These measurements were made as a check on the power entities flow determinations and to gather data for the calibration of the Lake Superior compensating works. This survey was undertaken by personnel from the Great Lakes Hydraulics and Hydrology Branch, Detroit District, U.S. Army Corps of Engineers, and from the Water Survey of Canada, Department of Environment.

3.17.2 Description of Sections.

The **U.S. Power Canal Section** was located approximately 2,300 feet upstream of the U.S. Government powerhouse in Sault Ste. Marie, Michigan. The section extended from a point on the Northwest Pier across the power canal to a point on the North Dike. Velocities at the 0.2 and 0.8 depths were sampled at about 40-foot increments across the section, and a unit discharge curve developed. From this curve, panel boundaries were established in such a manner that no one panel would pass more than 8 percent of the total flow through the section. The section was divided into a total of 20 panels. Between June 18 and 26, 1975, twelve discharge measurements were made at this section. Eight were taken between June 18 and 20, simultaneously with measurements at the Fort Street Bridge Section, and four of the measurements were taken on June 25 and 26, in conjunction with measurements at the Upper Gate Section.

The **Fort Street Bridge Section** was located at the upstream edge of the Fort Street Bridge over the Edison Soo power canal in Sault Ste. Marie, Michigan. The section was divided into 21 panels. Eight discharge measurements were made simultaneously at the Fort Street Bridge Section and the U.S. Power Canal Section, from June 18 through 20, 1975.

The **Upper Gate Section** was located approximately 1,100 feet upstream of the Lake Superior Compensating Works. This section began at a point on the south entrance pier of the Canadian ship canal and extended south to a point on the Northwest Pier. A unit discharge curve was developed and used for panel determination. Twenty-one panels were established such that no more than 8 percent of the flow passed through any panel. Four discharge measurements were made at the Upper Gate Section and the U.S. Power Canal Section, between June 25 and 26, 1975.

The **Upper Headrace Section** was located in Sault Ste. Marie, Ontario, to measure the total Canadian power diversion in the power canal, about 400 feet above the Great Lakes Power Company intakes. The 410 foot section was divided into 20 panels. Between June 18 and 20, 1975, ten discharge measurements were made at this section.

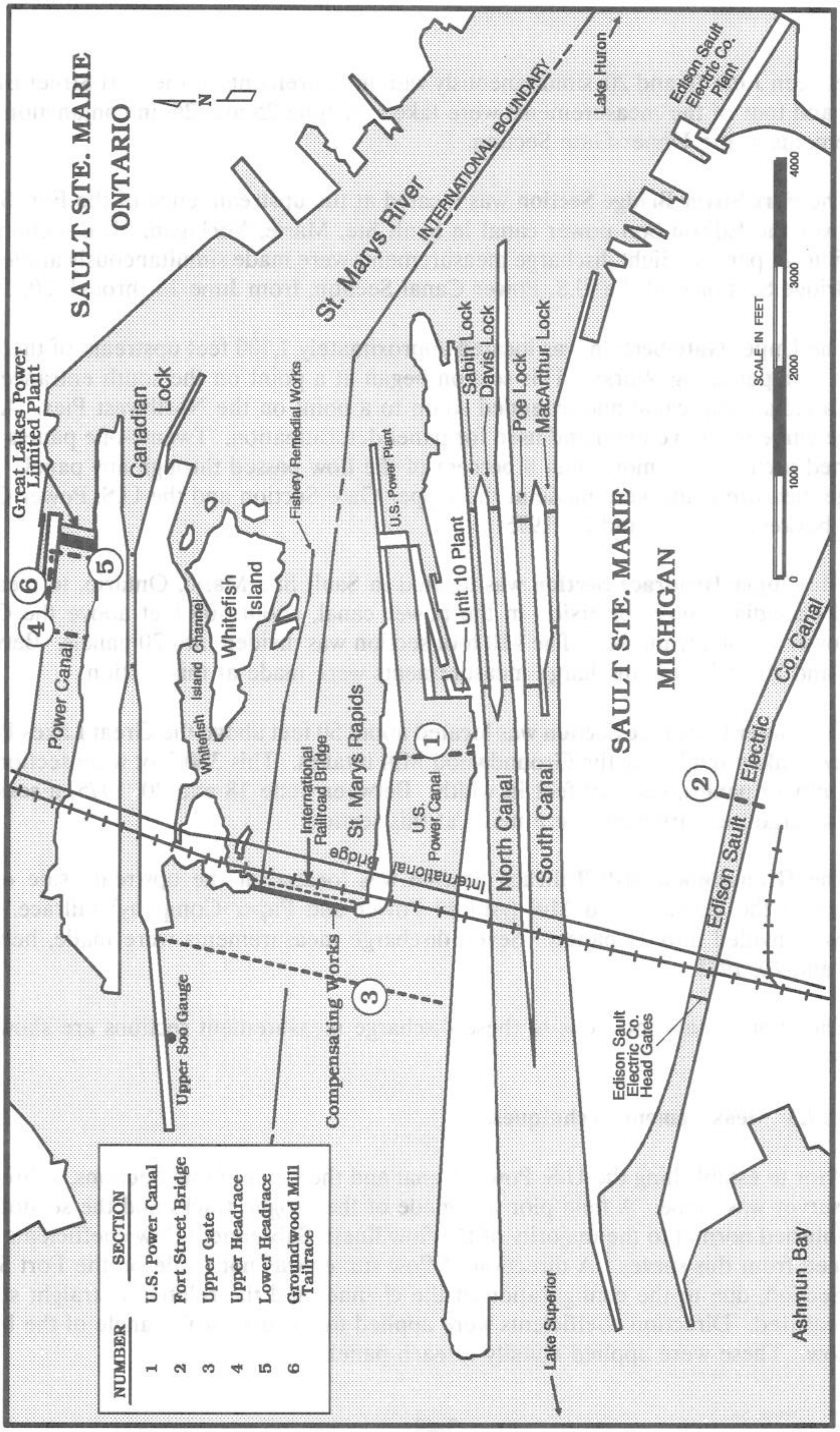
The **Lower Headrace Section** was located about 50 feet above the Great Lakes Power Company intakes and below the Groundwood Mill intakes. This 380 foot wide section was divided into 19 panels, each 20 feet in width. Between June 18 and 20, 1975, a series of seven discharge measurements were made at this section.

The **Groundwood Mill Tailrace Section** was located at the upstream side of the bridge across the Groundwood Mill (Abitibi Power and Paper Company) tailrace. The section was divided into 21 panels. Seven discharge measurements were made, between June 18 and 20, 1975.

The approximate locations of these discharge measurement sections are shown on Figure 3-15.

3.17.3 Measurement Techniques.

Prior to establishing the U.S. Power Canal and the Upper Gate Sections, a direction of flow survey was made. A field plot was made of the drogue tracks and the section line was established normal to the majority of the flow lines. Subsequent flow coefficients were determined from this survey. A direction of flow survey was not made on the Fort Street Bridge Section, due to the configuration of the channel and the relatively straight stretch being measured. Direction coefficients were applied to correct for the angle of the bridge to the flow. These were applied equally to each panel.



St. Marys River, 1975 Section Locations

Figure 3-15

The Fort Street Bridge, U.S. Power Canal, Upper Headrace, Lower Headrace and Groundwood Mill Tailrace Sections were lead-line sounded. The soundings for each section were reduced to common water surface elevations and plotted to create profiles of the sections. The Upper Gate Section was echo sounded. Three complete runs were made and an average of all three was taken to produce a standard profile of the section with all soundings reduced to a common water surface.

Water surface elevations used for the Upper Gate Section were taken from a water level recorder at the Upper Soo gauge, a permanent gauge owned and maintained by the Canadian Hydrographic Service. The Upper Soo gauge was also used to provide a record of the St. Marys River water levels above the rapids, for use in the computation of the discharge at the three Canadian sections. Staff gauges located at or near each of the three Canadian sections were used as section gauges. Water levels for the U.S. Power Canal Section were measured using a temporary water level recorder located 100 feet downstream of the section, on the north side of the Northwest Pier. At the Fort Street Bridge Section, periodic visual observations of the water elevation were made by measuring down from the bridge railing to the water surface and relating this distance to the elevation of the bench mark on the east side of the bridge (bench mark "Fort Street Bridge", elevation 610.932, IGLD 1955).

Metering stations at the Fort Street Bridge Section were located by marking the bridge railing at each station. Two metering cranes with a Price current meter and a 100-pound sounding weight suspended from them were used to take discharge measurements. At each panel, two-minute readings were made at every tenth of the total depth; that is, until the vertical measurements were completed.

At the U.S. Power Canal Section, positioning on the metering stations was accomplished by using a tag-line, which was extended across the section. For positioning on the metering stations at the Upper Gate Section, floats were set over the metering stations, using side ranges and a transit. Both these sections were measured using one of two launches equipped with four Price current meters suspended from four booms. The four meters took measurements simultaneously. One meter was kept at a constant 0.4 depth as an index meter. The remaining three meters were used to make measurements at each tenth of the total depth of the panel.

The Upper Headrace Section was metered in a manner very similar to that used on the U.S. Power Canal and Upper Gate Sections. Four Price, pattern 622AA, current meters were used simultaneously to measure each tenth of the total depth of a panel, with one of the four meters maintained at the 0.4 depth, as an index. One minute readings were made.

Seven discharge measurements were made at both the Lower Headrace and Groundwood Mill Tailrace Sections. Only one measurement at each of these sections was made at all of the tenth depths. For the remaining six measurements, only the 0.2, 0.4 and 0.8 depths were metered. All measurements were made using only one Price meter.

3.17.4 Discharge Computation.

The collected data were reduced using the Detroit District, Corps of Engineers, discharge measurement program. A brief description of the procedures used in the program is given in Appendix A. Data from the U.S. portion of this survey (1975) can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 75-30, of the Detroit District, Corps of Engineers, Detroit, Michigan. The results of the entire survey are located in file number GLHH 76-25, in report form. A summary of the discharge measurements is included in Tables 3.45 to 3.53 (see Appendix C). Tables 3.49, 3.52 and 3.53 reflect discharge measurements in addition to those referred to in the above write-up.

3.18 Frechette Point and Garden River Sections, 1976.

3.18.1 Purpose.

This project was undertaken as part of an Ice Boom Demonstration Study, at the request of the Detroit District, U.S. Army Corps of Engineers, Planning Branch. To study the effect an ice boom located above Little Rapids Cut has on flow, discharge measurements were made to obtain data for computing the flow distribution around Sugar Island.

3.18.2 Description of Sections.

The **Frechette Point Section** was originally established in 1965, re-established in 1969 and recovered for this survey. Located on the St. Marys River, approximately 4.5 miles southeast of Sault Ste. Marie, Michigan, the section extended from Frechette Point on the Michigan mainland across to Sugar Island. From east to west, the hydraulic section was divided into seven panels. Between February 24 and 27, 1976, a total of 12 measurements were made at this section. All panels were ice covered at the time.

The **Garden River Section** was originally established in 1965, re-established in 1969 and recovered for this study. The Garden River Section was located on the Lake George Channel, approximately 12 miles east of Sault Ste. Marie, Michigan, and about 1/2 mile downstream of the mouth of the Garden River. The section extended from State Park property on Sugar Island, Michigan, across the Lake George Channel to a point on the Canadian shore. The hydraulic section was divided into 6 panels. The first 27 feet of the section, off the Canadian waters edge, was almost solid ice and had no flow, so the first panel measured started 27 feet from shore. Panels 2 through 5 were ice free at the time measurements were made. Panel 6 ended 96 feet from Sugar Island, because thick ice obstructed water flow near the shore. Discharge measurements were made at the Garden River Section on February 26 and 27, 1976.

The locations of these discharge measurement sections are shown on Figure 3-14.

3.18.3 Measurement Techniques.

Both sections had been lead-line sounded, in 1969. For this series of measurements, depths were spot checked and found to compare closely with those of 1969. The section profiles of 1969 were adjusted to new surface elevations. The directions of flow past the Frechette Point and Garden River Sections were ascertained from direction of flow surveys, also made in 1969.

At the Frechette Point Section, the water surface elevations used in the discharge calculation were obtained from records at a water level recorder located at Frechette Point. This permanent gauge, owned and maintained by NOAA, is located approximately 500 feet upstream of the section. Visual observations were also periodically made and recorded for later use in discharge computations.

Discharge measurements were made at both sections using Price current meters. Each measurement consisted of two-minute readings taken individually at each one-tenth of the total depth for each panel. At the Frechette Point Section, all panels were measured through the ice using a sled type arrangement for holding the reel and lowering the meter to the various depths. The metering station locations were established by chaining off the respective distances and marking the points with wooden stakes. A hole was cut in the ice at each metering station to allow lowering of the meter into the water. Because the navigation season was still open on the St. Marys River and a shipping track was cut through the ice at various times, three sleds were used, one on the west side of the track, another in the area of the track and the third on the east side of the channel. Due to the frequency of ships passing through the section, it was impossible to measure panels 3 and 4 for every discharge measurement. To determine meter counts in those cases, plots of meter counts, when all panels were measured, were compared to the plot made of the measurement missing panels 3 and 4. Meter counts for panels 3 and 4 were then estimated to give a complete set of readings for that measurement.

At the panels where the ice was thick enough to hold a sled and technician (panels 1 and 6), the Garden River Section was measured in the same manner as the Frechette Point Section. In the open water area, a 14-foot aluminum hull boat equipped with one meter was used. Positioning was accomplished by placing section ranges and panel point ranges on shore.

3.18.4 Discharge Computation.

The collected data were reduced using the Detroit District, Corps of Engineers, discharge measurement program. A brief description of the procedures used in the program is given in Appendix A. The data and results of this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 76-7, of the Detroit District, Corps of Engineers, Detroit, Michigan. A summary of the discharge measurements is given in Tables 3.54 and 3.55 (see Appendix C).

3.19 Frechette Point, Garden River, Middle Neebish Channel, Field Point, Rock Cut and Little Rapids Island Sections, 1978.

3.19.1 Purpose.

This series of hydraulic discharge measurements were made as part of a project to obtain data for use in the calibration of a St. Marys River unsteady state flow model. This model was being developed by the Great Lakes Hydraulics and Hydrology Branch of the Detroit District, Corps of Engineers. All field work was carried out by personnel from this agency.

3.19.2 Description of Sections.

The **Frechette Point and Garden River Sections** were re-established from previous surveys. The Frechette Point Section was divided into seven panels, for metering purposes. The water level gauge for this section was the permanent water level recording gauge located at Frechette Point, currently owned and operated by NOS, NOAA. The Garden River Section was divided into six panels. The water level gauge for this section was the permanent recorder, owned by the Water Survey of Canada, located on the north shore (Canadian mainland) of the Lake George Channel, east of the Garden River confluence and east of the hydraulic section. On September 6, 1978 discharge measurements were made simultaneously at the Garden River and Frechette Point Sections. For a description of locations, see Subsection 3.14.

The **Middle Neebish Channel Section** was established to help determine the flow distribution around Neebish Island, on the St. Marys River. This hydraulic section, located across the Middle Neebish Channel, between Sugar Island and Neebish Island, was divided into eight panels. The section used an automatic water level recording gauge temporarily installed for this survey. Four measurements were made at this section, simultaneously with measurements made at the Rock Cut Section, between August 14 and 16, 1978. During the period August 17 to 30, 1978, seven more measurements were made, concurrent with measurements at the Field Point Section.

The **Rock Cut Section** was located across the West Neebish Channel in an area known as Rock Cut. The section extended from the Michigan mainland to Neebish Island and was made up of five panels. A series of 20 measurements were made at this section during the above mentioned three day period (August 14-16, 1978). The section's water level gauge, the Rock Cut gauge, is a Corps owned permanent water level recorder.

The **Field Point Section** was situated across the Middle Neebish Channel, downstream of the Middle Neebish Channel Section. It consisted of eleven panels and extended from Field Point on Neebish Island across to St. Joseph Island. This section was established to measure the total flow from the West Neebish Channel into Lake Munuscong. Between August 17 and 30, 1978, three measurements were made at this section, simultaneously with measurements at the Middle Neebish Channel Section. A board gauge at the section was used to measure the water levels, during the discharge measurements.

The **Little Rapids Island Section** was established between the United States mainland and the south tip of the southern most island in the Little Rapids Channel. The section was situated to measure the amount of flow that was naturally diverted from the main channel to flow along the Michigan shore. Twenty-three measurements were made at this section, on August 25, 1978. Water levels were recorded at the permanent recording Little Rapids gauge.

The approximate locations of these discharge measurement sections are shown on Figure 3-16.

3.19.3 Measurement Techniques.

All of the sections were sounded, prior to making discharge measurements, using an echo sounder. Velocity measurements were made at each one-tenth of the total depth of each panel point of all sections, except the Little Rapids Island Section. At this section only three out of a total of 23 measurements were full measurements. The remaining 20 measurements were made with index meters, at the center of the section, lowered to the 0.2, 0.4 and 0.8 depths. Price current meters were used for all discharge measurements.

3.19.4 Discharge Computation.

The collected data were reduced using the Detroit District, Corps of Engineers, discharge measurement program. A brief description of the procedures used in the program is given in Appendix A. The discharges that resulted from measurements made at the center of the Little Rapids Island Section were adjusted by a factor derived from the measurements made at all five panels of the section.

The data and results of this survey can be found in the Great Lakes Hydraulics and Hydrology Branch of the Detroit District, Corps of Engineers, Detroit, Michigan. A summary of the discharge measurements is given in Tables 3.56 to 3.60 (see Appendix C).

3.20 Frechette Point and Garden River Sections, Winter 1979.

3.20.1 Purpose.

The winter 1979 discharge measurements were made to obtain data for computing the flow distribution around Sugar Island; to be used in studying the effects of an Ice Boom located above Little Rapids Cut. The project was undertaken as part of an Ice Boom Demonstration, at the request of the Detroit District, Corps of Engineers, Hydraulics and Hydrology Branch; also, to augment St. Marys River and other hydraulic study flow data.

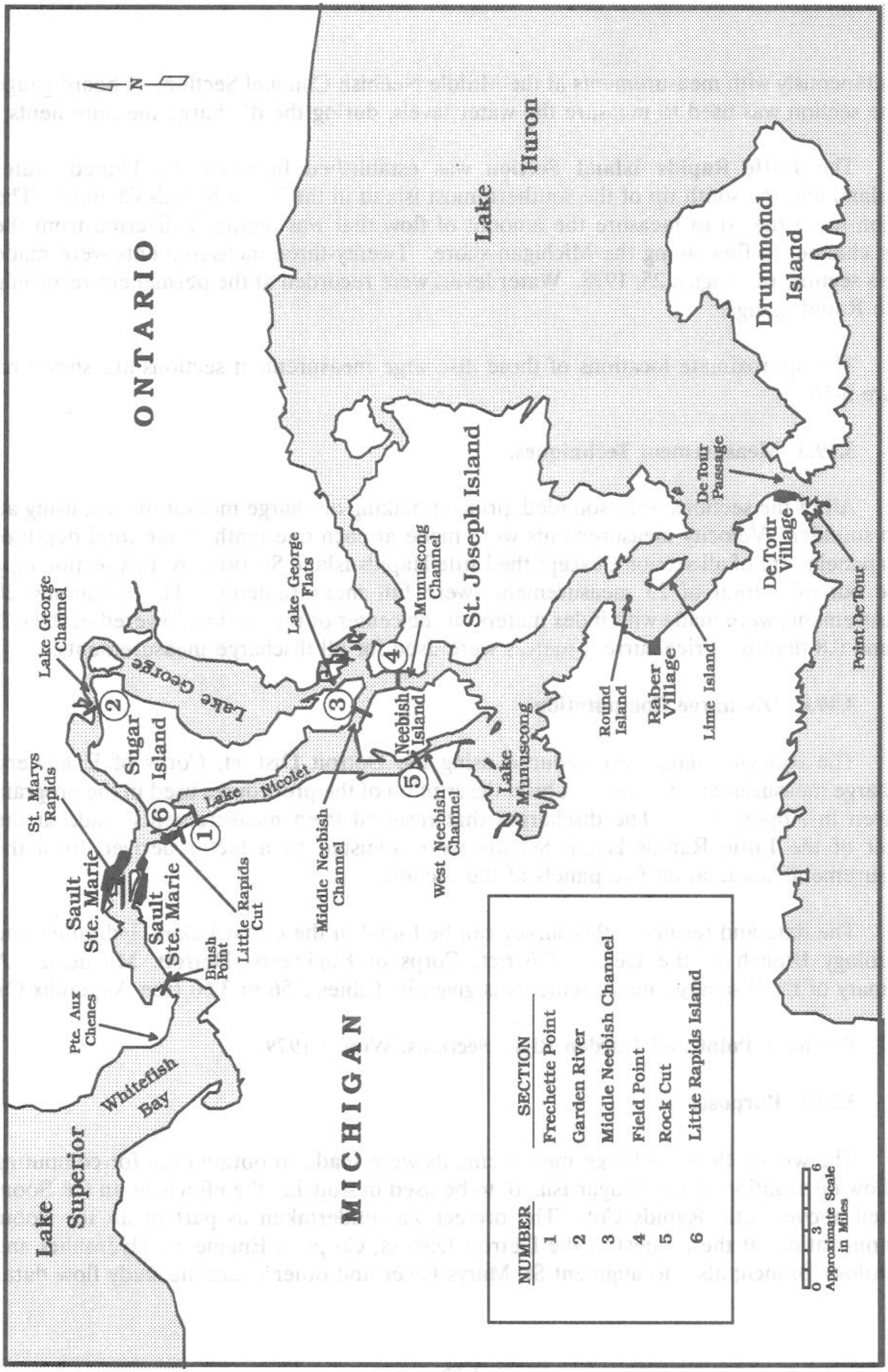

St. Marys River, 1978 Section Locations
ONTARIO
MICHIGAN
Lake Superior
Whitefish Bay
Pte. Aux Chenes
Brush Point
Sault Ste. Marie
Sault Ste. Marie
St. Marys Rapids
Little Rapids Cut
Sugar Island
Lake George Channel
Lake George
Lake Nicolet
Middle Neebish Channel
West Neebish Channel
Neebish Island
Lake George Flats
Munuscong Channel
Lake Munuscong
St. Joseph Island
Round Island
Raber Village
Lime Island
De Tour Passage
De Tour Village
Point De Tour
Drummond Island
Lake Huron
N
NUMBER
SECTION
1
Frechette Point
2
Garden River
3
Middle Neebish Channel
4
Field Point
5
Rock Cut
6
Little Rapids Island
0 3 6
Approximate Scale in Miles

Figure 3-16

3.20.2 Description of Sections.

The **Frechette Point Section** was originally established in 1965, re-established in 1969 and recovered for earlier surveys and for this survey. Located on the St. Marys River, approximately 4.5 miles southeast of Sault Ste. Marie, Michigan, the section extended from Frechette Point on the Michigan mainland across to Sugar Island. From east to west, the hydraulic section was divided into seven panels. Between February 27 and March 2, 1979, a total of 9 measurements were made at this section. All panels, except panel 3, were ice covered, when measurements were made.

The **Garden River Section** was originally established in 1965, re-established in 1969 and recovered for earlier surveys and for this survey. The section was located on the St. Marys River, approximately 12 miles east of Sault Ste. Marie, Michigan, extending from the northeastern shoreline of Sugar Island, Michigan, across the Lake George Channel to the Canadian mainland, at a point approximately 2,500 feet below the confluence of the Garden River. The section was divided into six panels. A total of 10 discharge measurements were made at this section under partial ice cover conditions, during the period February 26 to March 2, 1979. Panel points 1 and 6 were measured through 2 by 3 foot holes, which were cut through the ice. Panel points 2, 3, 4 and 5 were in open water (no ice cover), and were metered from a 14-foot aluminum boat.

The locations of these discharge measurement sections are shown on Figure 3-17.

3.20.3 Measurement Techniques.

Both sections were lead-line sounded in 1969 and were resounded using a Raytheon sounder. Lead-line soundings were taken at the panel points. The direction of flow survey made in 1969 was used for this series of measurements.

At the Frechette Point Section, the water surface elevations used in the discharge calculations were obtained from records of a water level recorder located at the Frechette gauge house, owned and maintained by the NOS, NOAA. At the Garden River Section, the water surface elevations were obtained from a permanent Water Survey of Canada gauge located on the Lake George Channel, about 0.5 mile below the Garden River Section on the Canadian shore.

Discharge measurements were made at both sections. Measurement at the Frechette Point Section consisted of nine settings at each panel (except for panel 3, where no measurements were taken). A Price current meter was used with one-minute readings taken individually at each one-tenth of the total depth for each panel. Effective panel depths were determined by substracting the ice thickness from the total depth measured at the water surface at each panel point. At the Frechette Section, panels were measured through the ice using a sled arrangement for holding the reel and lowering the meter and weight to the various depths. Since only one sled was available for use at Frechette for this set of

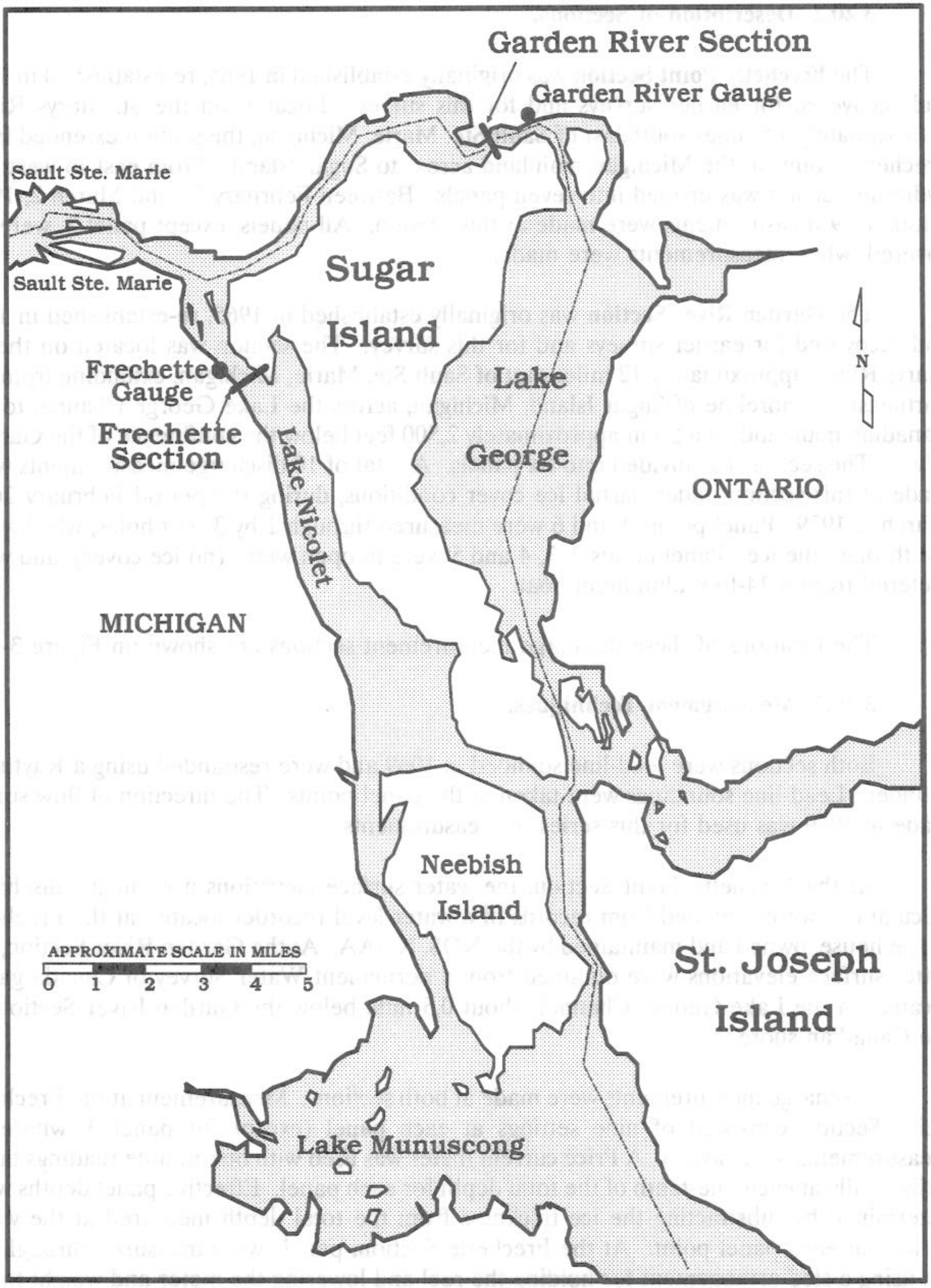


Figure 3-17

St. Marys River, Winter 1979 Section Locations

measurements and due to open water at panel 3, it was necessary to alternate between taking measurements from the Michigan mainland and from Sugar Island; i.e., panel points 1 and 2 were measured with the sled from the Michigan mainland side and then the sled was transported to Sugar Island via truck and ferry and panel points 4, 5, 6, and 7 were subsequently measured from that side. The Garden River Section panels 1 and 6 were measured in the same manner as Frechette, where the ice was thick enough to hold the sled and personnel. In open water panels 2 thru 5, a small boat was used with one meter. Positioning was accomplished by using ranges set up on shore. An anchor was dropped upstream of each panel and the boat maneuvered over the panel by using its motor and ranges. The second and the last of the measurements at Garden River were run at the 0.2, 0.4 and 0.8 depths only. The first and the third through ninth of the Garden River measurements were run at all nine-tenths depth settings.

3.20.4 Discharge Computation.

The collected data were reduced using the Detroit District, Corps of Engineers, discharge measurement program. With the velocities at each of the nine depths known, the average velocity in each vertical was computed. A modified von Karman equation was used to determine the configuration of the vertical velocity curve near the bottom, and to compute the average velocity in the vertical.

After the average velocity in the vertical was computed for each panel, the area under the transverse curve for each panel was computed. This was accomplished by fitting a parabolic equation through three adjacent vertical velocity points at a time. Then, the computer shifted over one vertical velocity point and fitted a curve through the next three points, and so forth, until the entire transverse curve was determined. In each case, the equation of the parabolic curve was integrated over the limits of the width of the panel to provide the area under the transverse curve for each panel. The area under the transverse velocity curve divided by the panel width was the average velocity for the panel, which was multiplied by the panel area to compute the panel discharge.

A modification to the above methodology involves the missing panel 3 data at the Frechette Section. To account for the fact that no data were actually acquired at panel 3 for these measurements, panels 2 and 4 were expanded in the von Karman equation to include panel 3. Also, the data for panel 3 from the 1976 set of measurements were averaged and a proportion was derived to account for higher velocities normally encountered at the third panel. The vertical velocities at this third panel were adjusted to account for this proportion.

The panel areas were multiplied by the average panel velocity and by a directional coefficient for the panel to determine the flow in the panel. Individual panel discharges were summed to obtain the total section discharge.

The above described procedure was followed for each discharge measurement. In summary, an individual vertical velocity curve was developed for each panel for each measurement, and the associated transverse velocity curve was developed for each discharge measurement. Using these techniques, errors introduced by the application of average vertical velocity and transverse velocity coefficients were obtained.

The data and results of this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 80-13, of the Detroit District, Corps of Engineers, Detroit, Michigan. A summary of the discharge measurements is given in Tables 3.61 and 3.62 (see Appendix C).

3.21 Frechette Point, Garden River, Middle Neebish Channel and Field Point Sections, 1979.

3.21.1 Purpose.

The 1979 discharge measurements were carried out by the Great Lakes Hydraulics and Hydrology Branch of the Detroit District, Corps of Engineers, in order to provide data to calibrate, at the time, an on-going Math Modeling Program on the St. Marys River. Also, the Frechette Point and Garden River Sections were included in order to determine if an Ice Boom, located above the Sugar Island Ferry Crossing, might have an effect on shoreline erosion in the North Channel, due to a retardation of flow through the Little Rapids Cut area. Discharge measurements were taken at the Middle Neebish Channel and Field Point Sections to determine the flow split through Stribling Point and Munuscong Channel.

3.21.2 Description of Sections.

The **Frechette Point Section** was originally established in 1965. For the section description, see Subsection 3.20.2. From east to west, the hydraulic section was divided into seven panels. Ten measurements were made at this section between June 13 and 16, 1979.

The **Garden River Section** was originally established in 1965. For the section description, see Subsection 3.20.2. The section was divided into six panels. A total of 12 discharge measurements were made at this section, simultaneously with measurements made at the Frechette Point Section (between June 13 and 16, 1979).

The **Middle Neebish Channel Section** was relocated upstream from the 1978 section, to the vicinity of the Cell Dock permanent Water Level gauge structure. The section was divided into nine panels. Panels 1 thru 7 were located between the north side of Neebish Island, at the Cell Dock, and the south side of a dike wall, approximately perpendicular to the flow. The south end of the section (panels 1-7) had a total distance of 876 feet. Panels 8 and 9, representing the north end of the section, had a distance of 1477 feet. Between June 21 and 28, 1979, twelve measurements were made at this section, simultaneously with measurements made at the Field Point Section.

The **Field Point Section** was situated across the Munuscong Channel, downstream of the Middle Neebish Channel Section. It consisted of eleven panels and extended from Field Point on Neebish Island across to St. Joseph Island. Between June 21 and 28, 1979, eight measurements were made at this section, simultaneously with measurements at the Middle Neebish Channel Section.

The locations of these discharge measurement sections are shown on Figures 3-17 and 3-18.

3.21.3 Measurement Techniques.

All sections were sounded prior to making discharge measurements. The determination of the flow direction at the panel points was made by a drogue tracking survey.

Discharge measurements were made using four Price current meters. One meter was held constant at the 0.4 depth of the panel. The three remaining meters were set at 0.3, 0.6 and 0.9 of the total average depth for two-minutes. After the two-minute period was reached, the counts were logged, together with the section staff readings, meter codes and time, along with any other relative data. The meters were then set to the 0.2, 0.5 and 0.8 depths for a two-minute interval and the counts were recorded; finally the meters were set at the 0.1, 0.4 and 0.7 depths for a two-minute interval, again the counts were recorded.

In the early spring of 1979, water level gauges were installed, by the Soo Area Office, Corps of Engineers, at the following locations.

1. Rock Cut (Lower Dam) - West Neebish Channel
2. Lookout #4 (Upper Rock Cut) - West Neebish Channel
3. Cell Dock (Middle Neebish Channel)
4. Slab Dock (Lower end, Munuscong Channel)

For this survey, the following gauges were used for the interpretation of water levels.

1. Little Rapids Gauge
2. Frechette Gauge
3. Rock Cut Gauge
4. Lookout #4 Gauge
5. Cell Dock Gauge
6. Field Point Board Gauge
7. Slab Dock Gauge
8. Garden River Board Gauge
9. Canadian Garden River Gauge
10. Detour Dock Gauge

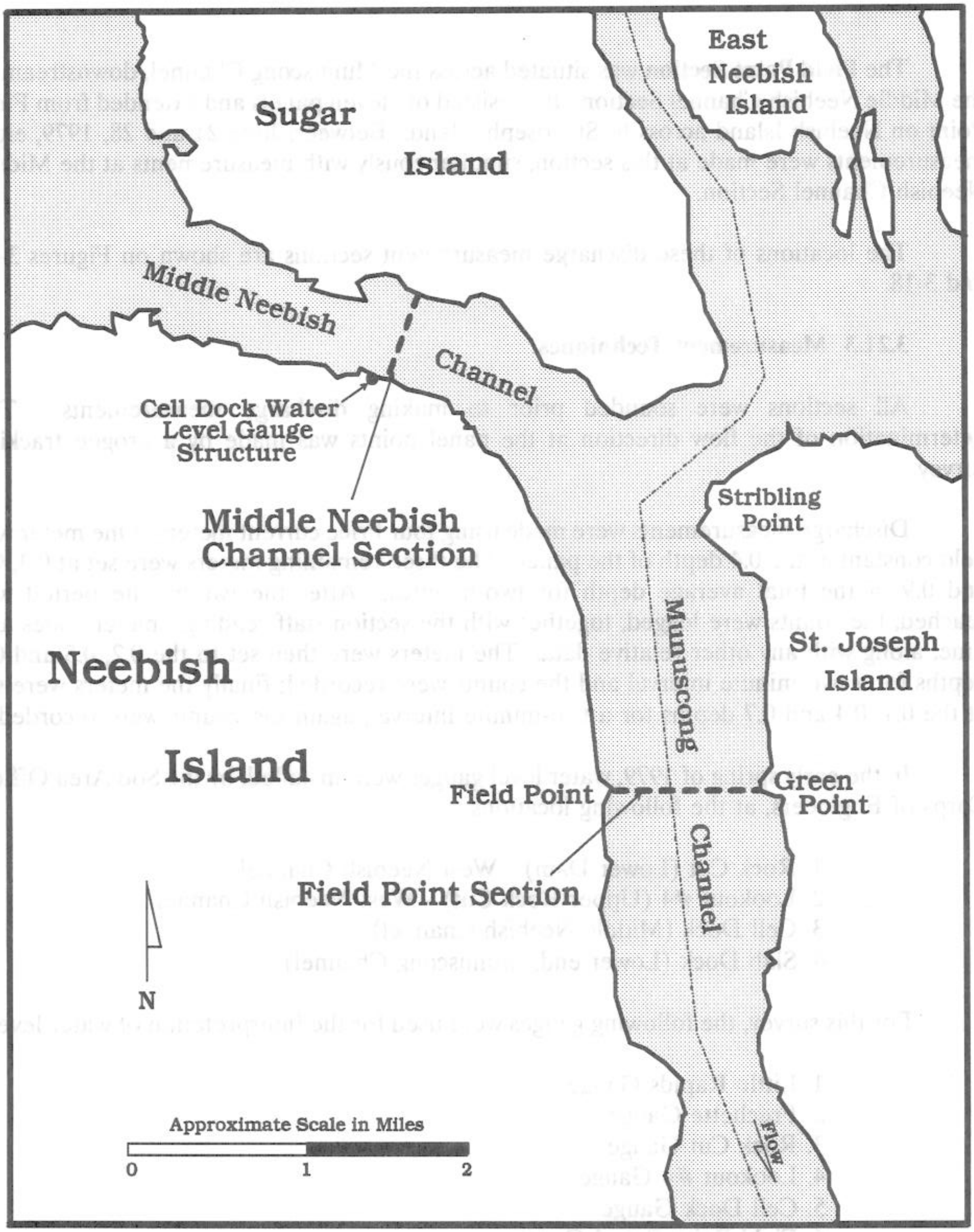


Figure 3-18

St. Marys River, 1979 Section Locations

3.21.4 Discharge Computation.

The collected data were reduced using the Detroit District, Corps of Engineers, discharge measurement program. A brief description of the procedures used in the program is given in Appendix A.

The data and results of this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archives, file number GLHH 86-2, of the Detroit District, Corps of Engineers, Detroit, Michigan; however, data for the Frechette Point and Garden River Sections are missing. A summary of the discharge measurements is given in Tables 3.63 and 3.64 (see Appendix C).

3.22 Garden River, Frechette Point and Rock Cut Sections, 1980.

3.22.1 Purpose.

The 1980 discharge measurements were carried out by the Great Lakes Hydraulics and Hydrology Branch of the Detroit District, Corps of Engineers, in order to provide data to calibrate, at the time, an on-going Math Modeling Program on the St. Marys River. Also, discharge measurements were made to obtain data for computing the flow distribution around Sugar Island, and from Lake Nicolet into West Neebish and Middle Neebish Channels.

3.22.2 Description of Sections.

The **Garden River Section** was originally established in 1965. For the section description, see Subsection 3.20.2. The section was divided into six panels. A total of 12 discharge measurements were made at this section, during the period July 23 to 29, 1980.

The **Frechette Point Section** was originally established in 1965. For the section description, see Subsection 3.20.2. From east to west, the hydraulic section was divided into seven panels. Between July 23 and 29, 1980, a total of 13 discharge measurements were made at this section.

The **Rock Cut Section** was located across the West Neebish Channel in an area known as Rock Cut. The section extended from the Michigan mainland to Neebish Island, and was made up of five panels. A series of 15 measurements were made at this section during the period July 23 to 29, 1980.

The locations of these discharge measurement sections are shown on Figure 3-19.

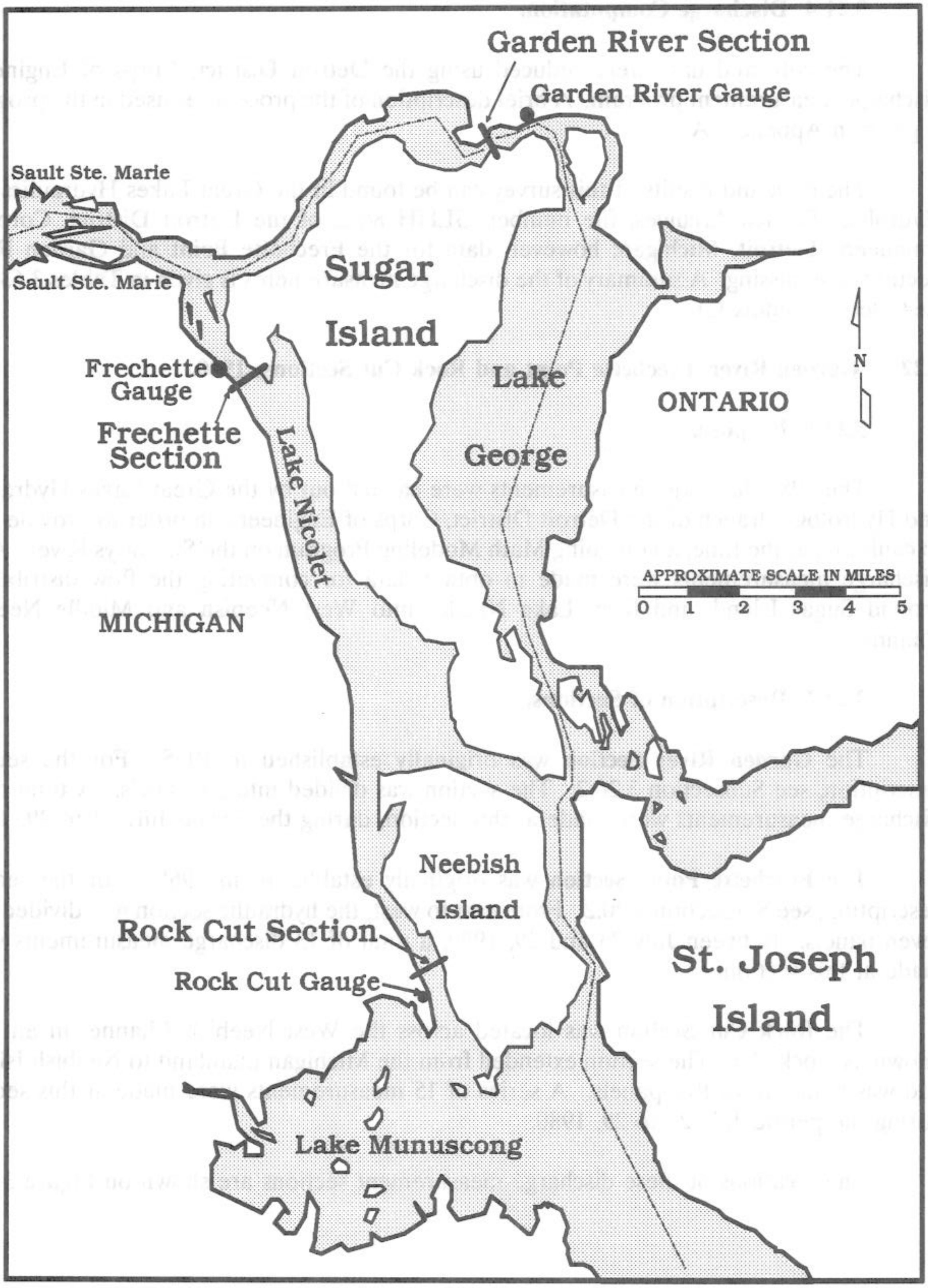


Figure 3-19

St. Marys River, 1980 Section Locations

3.22.3 Measurement Techniques.

All sections were sounded. Velocity measurements were made at each tenth depth of each panel point at all sections. Price current meters were used for all discharge measurements. For this survey, the Garden River, the Frechette Point and the Rock Cut gauges represent water levels at the respective sections.

3.22.4 Discharge Computation.

The collected data were reduced using the Detroit District, Corps of Engineers, discharge measurement program. A brief description of the procedures used in the program is given in Appendix A.

The data and results of this survey can be found in the Great Lakes Hydraulics and Hydrology Branch Archive, file number 86-2, of the Detroit District, Corps of Engineers, Detroit, Michigan. A summary of the discharge measurements is given in Tables 3.65 to 3.67 (see Appendix C).

3.23 Frechette Point and Garden River Sections, 1985-1986.

3.23.1 Purpose.

The 1985-86 discharge measurements were made by the Water Resources Branch, Ontario Region, Ontario, to obtain data for computing the flow distribution around Sugar Island.

3.23.2 Description of Sections.

The **Frechette Point Section** was originally established in 1965. For the section description, see Subsection 3.20.2. Three discharge measurements were made both during the period October 2 to 3, 1985 and during the period September 9 to 11, 1986.

The **Garden River Section** was originally established in 1965. For the section description, see Subsection 3.20.2. Three discharge measurements were made both during the period October 2 to 3,1985 and during the period September 9 to 11, 1986.

The locations of these discharge measurement sections can be found on Figure 3-19.

3.23.3 Measurement Techniques.

The entire survey was performed using an Automated Moving Boat Measurement System. In moving-boat measurements, the current meter is affixed to the boat at a set depth. The boat moves across the section in a continuous motion, from a starting buoy on one side of the channel to a finish buoy on the other side. An Ott propeller-type meter, which generates 24 electrical impulses per revolution, is usually mounted on a swivel rod over the bow or side of the boat at a depth of 3.3 feet. The impulses are transmitted by cable to an on-board pulse rate recorder and processor, where they are converted to a pulse rate and displayed on a panel. A discharge measurement consists of two traverses of the section in opposite directions. The average of the discharges computed from each traverse, corrected for distance and velocity-depth distribution, is the measured discharge. A detailed description of the technique is covered in the report:" Discharge Measurement Procedures on the Great Lakes Connecting Channels and the International Section of the St. Lawrence River", prepared by the Coordinating Committee on Great Lakes Basic Hydraulics and Hydrology Data, dated October 1991.

3.23.4 Discharge Computation.

The information on this survey was provided by the Water Survey of Canada. Tables 3.68 to 3.71 (see Appendix C) list the results of this survey.

3.24 U.S. Power Canal, Upper Gate and Fishway Flow-metering Sections, 1987.

3.24.1 Purpose.

In October 1987, the Detroit District, Corps of Engineers, in coordination with the Water Survey of Canada, initiated a program to update the hydraulic rating of the Compensating Works; located on the St. Marys River at Sault Ste. Marie, Michigan, and Sault Ste. Marie, Ontario. The discharge measurements were carried out for the purpose of verifying the ratings, for various gate settings and combinations of gate settings, of the Compensating Works.

3.24.2 Description of Sections.

The **U.S. Power Canal Section** was established in 1975 and re-established for this survey. This section was located in the U.S. Power Canal at Sault Ste. Marie, Michigan, and measured that portion of the flow entering the Unit 10 Powerhouse and the main Government Plant. A total of 6 discharge measurements were made at this section, during the period October 15 to 19, 1987.

The **Upper Gate Section** was established in 1975 and re-established for this survey. This section was located approximately 1,500 feet upstream of the Compensating Works, stretching from the north pier of the U.S. navigation locks to the south pier of the Canadian navigation lock. Measurements at this section provided the total flow through the Compensating Works as well as the flow entering the U.S. Power Canal. A total of 18 discharge measurements were made at this section, during the period October 15 to 23, 1987.

The Fishway Flow-metering Section was established for this survey. This section was located downstream of the Compensating Works' Gate 1, on the Fishery Remedial Works Channel; purpose, to measure that portion of the Compensating Works flow that entered the Channel. Two discharge measurements were made at this section, October 14 and October 17, 1987. The measurements were taken in accordance with Water Survey of Canada's wading standard procedures.

The locations of the U.S. Power Canal and the Upper Gate discharge measurement sections and the Fishery Remedial Works Channel can be found on Figure 3-15.

3.24.3 Discharge Computation.

Over the period October 13 to 24, discharge measurements were conducted at the U.S. Power Canal and Upper Gate Sections for settings of between one-half and 7 gates open (the 2 gates open setting was missed, because of inclement weather). Some measurements were also taken in the Fishery Remedial Works Channel. At each gate setting, depending on weather conditions, two or more measurements (using conventional techniques) were made.

Results of the measurement series did not meet the standards normally expected for conventional flow measurements. The excessive width of the Upper Gate Section (2,800 feet), combined with offlake winds, which affected positioning of the survey vessel over each measurement panel, undoubtedly caused some of the variations. The number of measurements per day (which was limited to two, because of the section width) and the fact that a specific gate setting was only held one day, resulted in a very small number of data samples for comparison with the existing gate rating equations.

The information on this survey was provided by the Great Lakes Hydraulics and Hydrology Branch, Detroit District, Corps of Engineers, and by the Water Resources Branch of Environment Canada. Tables 3.72 to 3.74 (see Appendix C) list the results of this survey.

3.25 Compensating Works, 1989.

3.25.1 Purpose.

In 1989, a series of discharge measurements were taken, jointly by the Corps of Engineers and the Water Survey of Canada, on the St. Marys River downstream of the Compensating Works, which is located on the St. Marys River at Sault Ste. Marie, Michigan, and Sault Ste. Marie, Ontario. Measurements previously taken in 1987 proved to be inadequate. This series included both conventional and moving-boat measurements. Measurements were carried out for the purpose of verifying the ratings, for various gate settings and combinations of gate settings. The moving-boat measurements were taken by the Water Survey of Canada, Hydrometric Methods Section, Ottawa, with manpower assistance from Water Survey of Canada, Ontario Region, which also assisted in the conventional measurements.

3.25.2 Description of Section.

Because the upstream sections established during the 1987 measurements proved to be inadequate for providing the needed data, it was decided to investigate a new hydraulic section at the foot of the St. Marys Rapids. The new section was established below the Compensating Works, between the U.S. Government Plant north tailrace dike and the eastern tip of Whitefish Island. The section was approximately 600 feet wide and provided the total flow through the Compensating Works. Figure 3-20 shows the location of the measurement section.

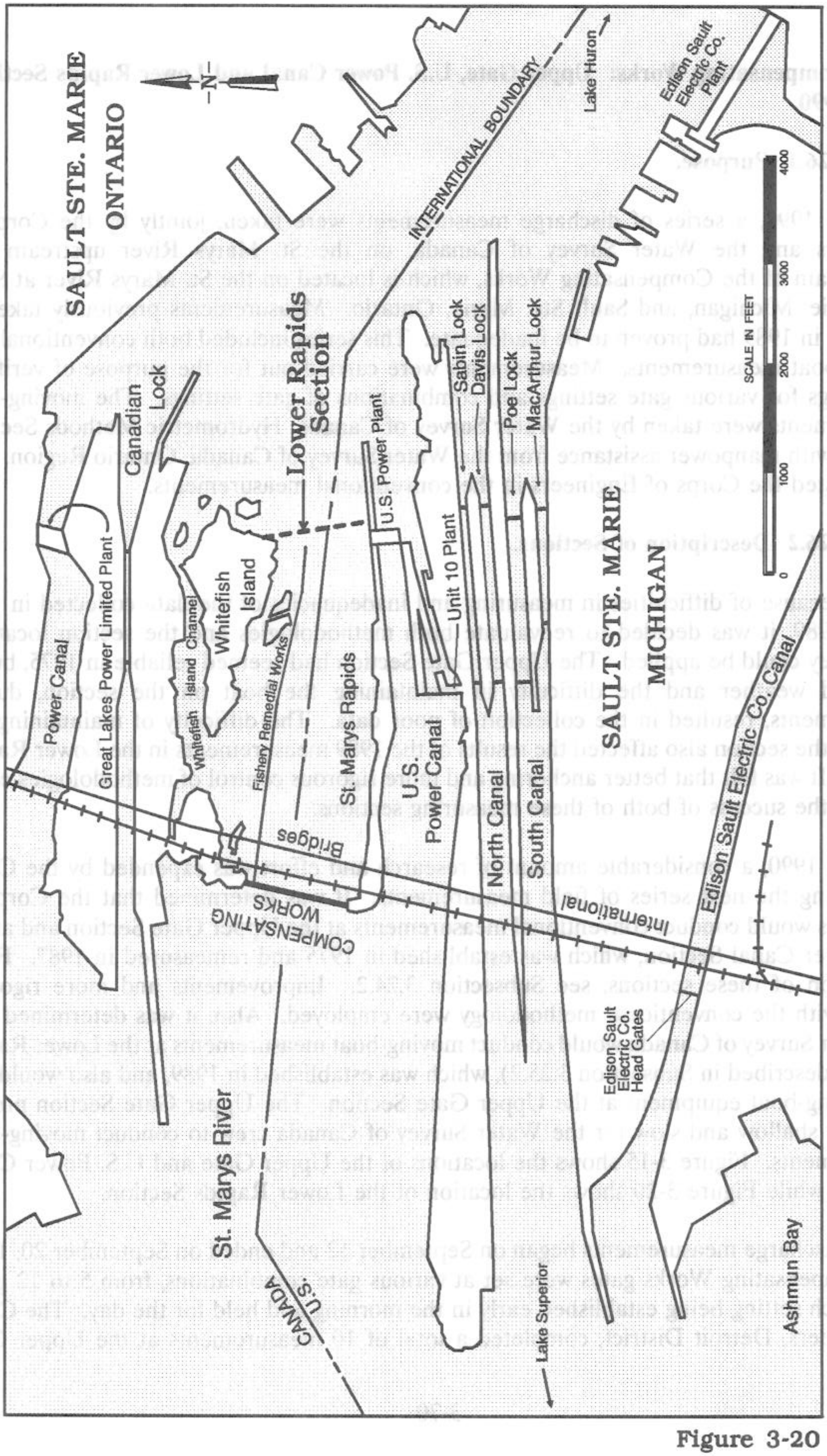
Field measurements began July 25 and ended August 3, 1989. The Compensating Works gates were set at various combinations, from one-half to 8 gates open, each setting being established early in the morning and held for the day. A total of 29 conventional measurements were taken, with about 3 or 4 measurements averaged per day. The Water Survey of Canada, using the moving-boat technique, completed 86 measurements.

3.25.3 Discharge Computation.

As stated above, during July 25 to August 3, 1989, discharge measurements were conducted at various combinations of gate settings, in order to collect velocity and discharge data. The Detroit District had one launch on site, conducting conventional measurements, while the Water Survey of Canada was concurrently conducting moving-boat measurements (approximately 10-15 measurements per day) and also assisting in the conventional measurements.

Results of this measurement series were not considered reliable. Problems were encountered with both of the measuring methodologies. At low gate settings, the boats could not traverse the entire section, because of shoals and boulders. At the higher gate settings, the boats experienced problems in maintaining position, because of turbulence. Nevertheless, it was felt that with better anchoring (conventional) and more experience (moving-boat), this section had some merit.

The information on this survey was provided by the Great Lakes Hydraulics and Hydrology Branch, Detroit District, Corps of Engineers, and by the Water Resources Branch of Environment Canada. Tables 3.75 and 3.76 (see Appendix C) list the results of this survey.



St Marys River, Compensating Works, 1989 Section Location

Figure 3-20

3.26 Compensating Works: Upper Gate, U.S. Power Canal and Lower Rapids Sections, 1990.

3.26.1 Purpose.

In 1990, a series of discharge measurements were taken, jointly by the Corps of Engineers and the Water Survey of Canada, on the St. Marys River upstream and downstream of the Compensating Works, which is located on the St. Marys River at Sault Ste. Marie, Michigan, and Sault Ste. Marie, Ontario. Measurements previously taken in 1987 and in 1989 had proven to be inadequate. This series included both conventional and moving-boat measurements. Measurements were carried out for the purpose of verifying the ratings for various gate settings and combinations of gate settings. The moving-boat measurements were taken by the Water Survey of Canada, Hydrometric Methods Section, Ottawa, with manpower assistance from the Water Survey of Canada, Ontario Region, who also assisted the Corps of Engineers in the conventional measurements.

3.26.2 Description of Sections.

Because of difficulties in measuring and inadequacies of the data collected in 1987 and in 1989, it was decided to reevaluate both methodologies and the section locations where they could be applied. The Upper Gate Section had seemed reliable in 1975, but in 1987 bad weather and the difficulty in maintaining the boat on the section, during measurements, resulted in the collection of poor data. The difficulty of maintaining the boats on the section also affected the results of the 1989 measurements in the Lower Rapids Section. It was felt that better anchoring and more rigorous control of methodologies could improve the success of both of these measuring sections.

In 1990, a considerable amount of research and effort was expended by the Corps engineering the next series of field measurements. It was determined that the Corps of Engineers would conduct conventional measurements at the Upper Gate Section and at the U.S. Power Canal Section, which was established in 1975 and remeasured in 1987. For a description of these sections, see Subsection 3.24.2. Improvements and more rigorous control with the conventional methodology were employed. Also, it was determined that the Water Survey of Canada would conduct moving-boat measurements at the Lower Rapids Section (described in Subsection 3.25.2), which was established in 1989, and also would test the moving-boat equipment at the Upper Gate Section. The Upper Gate Section proved to be too shallow and slow for the Water Survey of Canada crew to conduct moving-boat measurements. Figure 3-15 shows the locations of the Upper Gate and U.S. Power Canal Sections, while Figure 3-20 shows the location of the Lower Rapids Section.

Discharge measurements began on September 12 and ended on September 20, 1990. The Compensating Works gates were set at various gate combinations, from 5 to 12 gates open; each setting being established early in the morning and held for the day. The Corps of Engineers, Detroit District, completed a total of 10 measurements at the Upper Gate

Section and 16 measurements at the U.S. Power Canal Section, utilizing the conventional fixed-boat methodology from two survey launches. The Water Survey of Canada, using the moving-boat technique, completed 120 measurements at the Lower Rapids Section. These included two measurements, on September 11, 1990, at the 1/2 gate open setting; being conducted prior to the start of the measuring program proper.

An acoustic velocity meter was also installed at the foot of the rapids, below the Compensating Works, by the Water Survey of Canada. Problems were encountered, due to turbulence in the rapids, and the acoustic velocity meter was removed from operation after the second day.

3.26.3 Discharge Computation.

As stated above, during September 12 to September 20, 1990, discharge measurements were conducted at various combinations of gate settings, in order to collect velocity and discharge data. The Detroit District, with two launches on site, conducted conventional measurements at the Upper Gate Section and at the U.S. Power Canal Section, while the Water Survey of Canada concurrently conducted moving-boat measurements at the Lower Rapids Section and also assisted in the conventional measurements.

The flows measured at the Upper Gate and U.S. Power Canal Sections, using the conventional methodology, were successful. The measurements in the U.S. Power Canal Section were consistent with the average daily flow calculated through the U.S. Powerhouse. The measured flow through the Compensating Works was determined by subtracting the flow measured at the U.S. Power Canal Section from that measured at the Upper Gate Section. These flows correlated well with the 1931 rating equations, which included an adjustment for leakage through the closed gates and flow through the Fishery Remedial Works. Seven of the ten measured flows were within 8 percent of the computed flows; all were within 13 percent. The flows measured at the Lower Rapids Section correlated well with the Upper Gate Section measurements, as well as with the 1931 rating equations. Most measured flows were within 8-10 percent of the computed flows.

It was decided that, for further measurements at the Compensating Works, both the Upper Gate Section, employed for the conventional measurements, and the Lower Rapids Section, employed for the moving-boat measurements, appear to be good sections for measuring at the higher gate settings. For the lower gate settings, the Lower Rapids Section can be used for both conventional and moving-boat measurements.

The information on this survey was provided by the Great Lakes Hydraulics and Hydrology Branch, Detroit District, Corps of Engineers, and by the Water Resources Branch of Environment Canada. Tables 3.77 and 3.78 (see Appendix C) list the results of this survey.

3.27 Compensating Works: Upper Gate, U.S. Power Canal and Lower Rapids Sections, 1991.

3.27.1 Purpose.

In 1991, a series of discharge measurements were taken, jointly by the Corps of Engineers and the Water Survey of Canada, on the St. Marys River upstream and downstream of the Compensating Works, which is located on the St. Marys River at Sault Ste. Marie, Michigan, and Sault Ste. Marie, Ontario. Measurements previously taken in 1990 had proven to be successful and this series of measurements continued to obtain data at the gate settings not measured in 1990. The series included both conventional and moving-boat measurements. Measurements were carried out for the purpose of verifying the ratings for various gate settings and combinations of gate settings. The moving-boat measurements were taken by the Water Survey of Canada, Hydrometric Methods Section, Ottawa, with manpower assistance from the Water Survey of Canada, Ontario Region, who also assisted the Corps of Engineers in the conventional measurements.

3.27.2 Description of Sections.

In 1990, a considerable amount of research and effort was expended by the Corps engineering the future series of field measurements for the Compensating Works rating equation verification. It was determined that both the Upper Gate Section, utilizing the conventional methodology, and the Lower Rapids Section, utilizing the moving-boat methodology, appeared to be good sections for measuring at the higher gate settings. Also, due to low velocities, the Upper Gate Section should not be utilized for less than 4 gates open. Further, for the lower gate settings (3 gates open and less), the Lower Rapids Section should be used for gathering both conventional and moving-boat data. For a description of the Upper Gate Section and the U.S. Power Canal Section, see Subsection 3.24.2; the Lower Rapids Section is described in Subsection 3.25.2. Figure 3-15 shows the locations of the Upper Gate and U.S. Power Canal Sections, while Figure 3-20 shows the location of the Lower Rapids Section.

Between August 14 and August 17, 1991, measurements were made at gate settings ranging from 1 to 4 gates open. The Detroit District, utilizing one launch, performed conventional fixed-boat measurements in the Lower Rapids Section, completing a total of 11 measurements. The Water Survey of Canada, using the moving-boat technique, completed, during this same week, 43 measurements at the Lower Rapids Section.

Measurements were made, between August 20 and August 23, 1991, for a range of 13 to 16 gates open. The Detroit District, utilizing two launches, performed simultaneous conventional fixed-boat measurements in the Upper Gate and U.S. Power Canal Sections. A total of 10 measurements were completed at the Upper Gate Section and 12 were completed at the U.S. Power Canal Section. The Water Survey of Canada, using the moving-boat technique, completed, during this same week, 82 measurements at the Lower Rapids Section.

An acoustic velocity meter had been installed below the rapids, near the Lower Rapids Section, earlier in the year. Problems were again encountered from noise, due to turbulence in the rapids, at higher flows and no useful data were obtained. The Water Survey of Canada recommended that a new location for the meter be investigated.

In a separate effort related to the verification of the 1931 gate rating equations, consideration was given to determine the general extent of the leakage through the closed gates of the Compensating Works. Currently, an estimate of 25 cfs per closed gate is being used to adjust the computed flows for comparison purposes. This value was determined shortly after the gates were constructed and has been used since the original rating in 1931. While some maintenance work has been done over the years (the 8 U.S. gates had new rubber seals added to their upstream face, in the summer of 1976), leakage is still readily apparent at all 16 gates.

On August 13, 1991, a visual inspection of 14 closed gates was made and recorded on videotape; gate 1 was partially open for the Fishery Remedial Works flow and gate 10 was one-half open. Five gates were chosen to be representative of the range of leakage. Limited flow measurements were conducted on August 13 and August 14, 1991, at closed gates 16, 14, 11, 5 and 3. They were performed using a moveable cart on the walkway of the Compensating Works. A standard Price meter was suspended over the railing on the down-stream side of the gate; about 2 feet out from the gate. Readings were taken at the 2, 4 and 8 tenths depths at four points across each gate, one near each pier face and two evenly spaced from the middle.

Additionally, in November 1991, as part the Detroit District dam safety program, an underwater inspection was conducted on the U.S. side of the Compensating Works. The inspection was performed, by a contractor utilizing a remotely operated submersible vehicle, for the purposes of checking the stability of the structure and to determine the condition of previous repairs. The contractor's inspection report noted that "a significant number of the gate guides evidenced high volume leakage". It also noted several instances of gaps under the gates, some as much as 1-1/2 inches, where daylight could be seen. The original recessed wood seals in the concrete apron appeared deteriorated, or missing in some instances, and the high velocity under the gate was causing the rubber side seals to bend downstream and not function correctly. A videotape of this inspection is available in the Geotechnical Engineering Section of the Detroit District.

3.27.3 Discharge Computation.

As stated above, during August 14 to August 23, 1991, discharge measurements were conducted at various combinations of gate settings, in order to collect velocity and discharge data. The Detroit District had two launches on site, conducting conventional measurements at the Upper Gate, U.S. Power Canal and Lower Rapids Sections, while the Water Survey of Canada was concurrently conducting moving-boat measurements at the Lower Rapids Section and assisting in the conventional measurements.

The flows measured in the 1991 program, using the conventional methodology, at the Lower Rapids Section, were successful. A comparison between the conventionally measured flows, for 1 to 4 gates open, and the computed flows show that the measured flows correlated well with the flows computed from the rating equations. All eleven measured flows were within 6.5 percent of the computed flows. The computed flows were determined using the 1931 rating equations and include estimates of the flow through the Fishery Remedial Works (500 cfs) and leakage through the closed gates (25 cfs per closed gate).

The results of the conventional measurements made at 13 to 16 gates open were also successful. The measurements at the U.S. Power Canal Section were consistent with previous measurements at that section. The measured flow through the Compensating Works was determined by subtracting the flow measured at the U.S. Power Canal Section from the flow measured at the Upper Gate Section. Again the computed flows were determined using the 1931 rating equations and included estimates of the flow through the Fishery Remedial Works and leakage through the closed gates. The comparison between the computed flows for 13 to 16 gates open and the flows through the Compensating Works show that the measured flows correlated well with the flows computed from the rating equations. Six of the eight measured flows were within 4 percent of the computed flows, with the remaining two measurements deviating from the computed flows by 15 and 10 percent. The 10 percent deviation occurred on the afternoon of August 22, at a time of high winds. This may have caused more water to pass through the gates than is indicative of levels from the section gage. A review of the moving boat measurements taken during the same time period also show a high positive skew in flow. The plus 15 percent deviation, occurring on August 21, was reviewed for probable cause with no obvious problems found. Both of these measurements will be removed from the data sets as outliers.

The results of the 1991 moving-boat measurements made at the Lower Rapids Section at 1 to 4 and 13 to 16 gates open were compared to the computed flows, which were determined in the same way as that for the conventional measurements. These measurements were generally consistent with the flows measured conventionally at the Upper Gate and Lower Rapids Sections, with respect to their positive and negative deviations from the computed flows at the same gate settings. Of the 125 moving boat measurements conducted, 64 percent correlated within 10 percent of the computed flows, while 36 percent exceeded a 10 percent deviation. It was generally observed from this measurement set that the moving-boat method produces its best results at the higher flows provided by the 13 to 16 gate open settings.

The results of the leakage measurements were considered inadequate. Leakage appears to come from the bottom and sides of the gates and sets up a swirling flow pattern with several feet of standing water behind the gates. With the simple methodology used, such conditions made determination of flow, due only to leakage, difficult. Although the measurements were not reliable, due to flow patterns, it appears that leakage was more than 25 cfs per gate, especially through gates 2 through 8.

When the measurement program was conceived, it was determined that it would take several years to not only develop the techniques to be used but to also obtain enough representative data. Based on the results to date, the field methodology has been resolved. All of the measurements made for verifying the Compensating Works rating equations, to date, have been within the same general range of Lake Superior water levels. Measurements conducted in 1987, 1989, 1990 and 1991 were made when the level of Lake Superior was within the range of 600.08 to 600.99 feet (IGLD 1955), with most falling within a narrow band between 600.00 and 600.50 feet (IGLD 1955) (daily means measured at the Pt. Iroquois gage). Further measurements will be required to rate the standard gate combinations over a wider range of levels on Lake Superior; that is, to ensure that an adequate data population exists to evaluate the 1931 stage-discharge relationships for the gates. It is recommended that the measurement program continue to collect data only when the level regime of Lake Superior is at or above 601.00 feet (IGLD 1955), or below 600.00 feet (IGLD 1955).

The information on this survey was provided by the Great Lakes Hydraulics and Hydrology Branch, Detroit District, Corps of Engineers, and by the Water Resources Branch of Environment Canada. Tables 3.79 through 3.81 (see Appendix C) list the results of this survey.

3.28 Summary of Discharge Measurements.

For easy reference, a matrix of the identifiable historical St. Marys River discharge measurements is provided in Table 3.1. The table contains only basic information in an abbreviated format; therefore, for more information on a particular series of measurements refer to the noted subsection in the table.

TABLE 3.1 Summary of St. Marys River Discharge Measurements

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
St. Marys Rapids **(See Subsection 3.1)**	July 3 - Aug. 5, 1867	To measure outflow from Great Lakes	At Sault Ste. Marie, MI, one mile below St. Marys Rapids	Floats	Tables 3.1 & 3.2
Bridge **(See Subsection 3.2)**	Dec. 24, 1895 - March 24, 1896	To measure flow through St. Marys Falls (Rapids)	Downstream side of the International Railroad Bridge	Bridge	Table 3.3
Spry Dock **(See Subsection 3.3)**	Feb. 8 - Mar. 23, 1896 & Feb. 18 - Apr. 4, 1899	To measure entire river flow, just below St. Marys Falls (Rapids)	Below St. Marys Rapids at Spry Dock	Through holes in ice	Tables 3.4 & 3.5
International Bridge **(See Subsection 3.4)**	Dec. 4 & 27, 1899 & July 12 - Nov. 26, 1901 & July 31 - Nov. 8, 1902	To determine effect on St. Marys Rapids flows of closing ninth and tenth spans of International Railroad Bridge	International Railroad Bridge	Bridge	Tables 3.6 - 3.8
Brewery **(See Subsection 3.5)**	Feb. 9 - March 22, 1905	To measure total flow from Lake Superior	Below St. Marys Rapids, about 2000 ft. below Spry Dock Section	Through holes in ice	Table 3.9
International Bridge, **(See Subsection 3.6)**	Sept. 18 - 27, 1909	To measure Lake Superior outflow by measuring the flow over the rapids and through the powerhouses	International Railroad Bridge (spans 3 to 10)	Bridge	Table 3.10
Bingham Avenue,	Aug. 19 - 21, 1909		Bingham Avenue Bridge over the Michigan Lake Superior Power Company Power Canal	Bridge	Table 3.11
Float,	Aug. 24 - 25, 1909		Edison Sault Electric Company plant's headrace	Rod Floats	Table 3.12
Bridge &	Sept. 16 - 21, 1909		Spans 1 and 2 of the International Railroad Bridge	Bridge	Table 3.13
Lake Superior Corporation	Sept. 3 - 7, 1909		Canadian Company's power canal, about 1300 ft. above the powerhouse	Cableway	Table 3.14

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Compensating Works **(See Subsection 3.7)**	March 8, 1927 - Aug. 17, 1930	To determine how much water flows through various gate settings and combinations of gate settings	Parallel to and 150 ft. upstream of the International Railroad Bridge	Compensating Works; also, pitot tube observations	Tables 3.15 - 3.17
Bingham Avenue, **(See Subsection 3.8)**	August 5 - 7, 1935	To check the calibrations upon which the St. Marys River discharge was based. Specifically, to test the computed flow through the compensating gates for a small and large discharge and to check one point on the rating of each power plant.	Bingham Avenue Bridge over the Michigan Northern Power Canal	Bridge	Table 3.18
Edison Sault Tailrace,	August 8 - 12, 1935		Edison Sault Electric Company power plant tailrace, about 1/4 mile east of plant	Conventional	Table 3.19
Canadian Power Canal,	August 13 - 20, 1935		Headrace of the Power Canal	Cableway	Table 3.20
Little Rapids &	June 18 - July 31, 1935		Three miles below Sault Ste. Marie, MI, at the upper end of Little Rapids Cut	Conventional	Table 3.21
Garden River	July 10 - Aug. 2, 1935		On the Lake George Channel, just below the mouth of the Garden River	Conventional	Table 3.22

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Brush Point, **(See Subsection 3.9)**	July 12 - 30, 1965	To determine the distribution of flow through the various channels of the St. Marys River	Six miles upstream of the St. Marys Rapids	Conventional	Table 3.23
Frechette Point,	Sept. 15 - Oct. 6, 1965		Six miles below the St. Marys Rapids in the lower end of the Little Rapids Cut Channel		Table 3.24
Garden River,	Sept. 14 - Oct. 5, 1965		On the Lake George Channel, about 2500 ft. downstream of the confluence of the Garden River		Table 3.25
West Neebish Channel,	Aug. 20 - Sept. 7, 1965		On the lower end of the West Neebish Channel		Table 3.26
Middle Neebish Channel &	Aug. 19 - Sept. 8, 1965		On the Middle Neebish Channel, between Neebish Island and Sugar Island		Table 3.27
Power Canal	Sept. 2 - 16, 1965	To check the calibration of the powerhouse	On U.S. Power Canal, about 1250 ft. above the powerhouse		Table 3.28
Compensating Works **(See Subsection 3.10)**	May 29 - June 4, 1969	To check the accuracy of St. Marys River flows computed using Corps of Engineers discharge equations	Lake Survey Section - about seven ft. east (downstream) of Compensating Works; Water Survey of Canada Section - about 500 ft. upstream of Compensatingn Works	Conventional and Bridge	Tables 3.29 & 3.30

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Frechette Point, **(See Subsection 3.11)**	Sept. 18 - 27 & Oct. 16 - 21, 1969	To obtain data for computing the amount and distribution of flow through various channels of the St. Marys River - Also, to provide for development of a mathematical model of the lower river	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Conventional	Table 3.31
Garden River,	Sept. 18 - 27 & Oct. 16 - 21, 1969		Northeast shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence		Table 3.32
Middle Neebish &	Oct. 2 - 13, 1969		On the Middle Neebish Channel, between Neebish Island and Sugar Island		Table 3.33
West Neebish	Oct. 2 - 13, 1969		On the lower end of West Neebish Channel		Table 3.34
Bamford Island, **(See Subsection 3.12)**	Oct. 28, 1969, Nov. 15, 1988 & Aug. 4, 1989	To determine flow in the St. Joseph Channel of the St. Marys River	On the northwest side of Bamford Island, under the bridge for Highway 548	Conventional	Table 3.35 & 3.36
Ferry Channel &			Across the main channel, between Ferry Landing on Bamford and Twyning Islands		
Munroe Island			Munroe Island to St. Joseph Island, under the bridge for Highway 548		

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Compensating Works **(See Subsection 3.13)**	July 23 - Aug. 16, 1971	To investigate how various gate settings affect fish and other aquatic life in St. Marys Rapids	At Compensating Works, upstream side	Compensating Works	Tables 3.37 - 3.38
Frechette Point & **(See Subsection 3.14)**	Dec. 11 - 14, 1971 & Feb. 4 - 8, 1972	To determine the effect a natural ice cover has on St. Marys River flows around Sugar Island	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Conventional and through holes in the ice	Tables 3.39 & 3.40
Garden River	Dec. 11 - 15, 1971		Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence	Conventional	Table 3.41
Frechette Point & **(See Subsection 3.15)**	Feb. 17 - 21, 1973	To determine the effect an ice cover has on flow velocity distribution around Sugar Island	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Through holes in the ice	Table 3.42
Garden River			Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence		Table 3.43
Compensating Works **(See Subsection 3.16)**	June 13 - 27, 1974	To check the calibration of the Compensating Works	At Compensating Works, upstream side	Compensating Works	Table 3.44

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
U.S. Power Canal, (See Subsection 3.17)	June 18 - 26, 1975	As a check on the power entities flow determination and to gather data for the calibration of the Compensating Works	About 2300 ft. upstream of U.S. Gov't powerhouse, in Sault Ste. Marie, MI	Conventional	Table 3.45
Fort Street Bridge,	June 18 - 20, 1975		Upstream edge of the Fort Street Bridge over the Edison Soo power canal, in Saulte Ste. Marie, MI		Table 3.46
Upper Gate,	June 25 - 26, 1975		About 1100 ft. upstream of the Compensating Works		Table 3.47
Upper Headrace,	June 18 - 20, 1975, Data in addition to this survey: July 19, 1943 - June 20, 1975 (Table 3.49)	To measure the total Canadian power diversion in the power canal	In Sault Ste Marie, Ont., about 400 ft. above the Great Lakes Power Company intakes		Tables 3.48 & 3.49
Lower Headrace,	June 18 - 20, 1975		About 50 ft. above the Great Lakes Power Company intakes and below Groundwood Mill intakes		Table 3.50
Groundwood Mill Tailrace	June 18 - 20, 1975 Data in addition to this survey: Aug. 22, 1973 - June 20, 1975 (Table 3.52) & Sept. 8, 1957 - Oct. 9, 1963 (Table 3.53)		Upstream side of the bridge across the Groundwood Mill tailrace		Tables 3.51 - 3.53
Frechette Point & (See Subsection 3.18)	Feb. 24 - 27, 1976	To study the effect an ice boom located above Little Rapids Cut has on flow; discharge measurements were made to determine flow distribution around Sugar Island	On St. Marys River about 4.5 miles southeast of Sault Ste. Marie, MI	Through holes in the ice and Conventional	Table 3.54
Garden River	Feb. 26 - 27, 1976		On the Lake George Channel, about 2500 ft. downstream of the confluence of the Garden River		Table 3.55

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Frechette Point, (See Subsection 3.19)	Sept. 6, 1978	To obtain data for use in calibration of a St. Marys River unsteady state model	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Conventional	Table 3.56
Garden River,	Sept. 6, 1978		Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence		
Middle Neebish Channel,	Aug. 14 - 16, 1978 & Aug. 17 - 30, 1978		On the Middle Neebish Channel, between Sugar Island and Neebish Island		Table 3.57
Field Point,	Aug. 17 - 30, 1978		Across Middle Neebish Channel, downstream of the Middle Neebish Channel Section, from Neebish Island to St. Joseph Island		Table 3.58
Rock Cut &	Aug. 14 - 16, 1978		On the West Neebish Channel, from MI mainland to Neebish Island (area known as Rock Cut)		Table 3.59
Little Rapid Island	Aug. 25, 1978		Between U.S. mainland and south tip of the southern most island in the Little Rapids Channel		Table 3.60
Frechette Point & (See Subsection 3.20)	Feb. 27 - March 2, 1979	To obtain data for computing the flow distribution around Sugar Island; for use in studying the effect of an Ice Boom located above Little Rapids Cut	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Through holes in the ice and Conventional	Table 3.61
Garden River	Feb. 26 - March 2, 1979		Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence		Table 3.62

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Frechette Point, (See Subsection 3.21)	June 13 - 16, 1979	To provide data to calibrate an on-going Math Modeling Program on the St. Marys River; to determine if an ice boom located above the Sugar Island Ferry Crossing might have an effect on shoreline erosion in the North Channel; to determine flow split through Stribling Point and Munuscong Channel	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Conventional	Not Recovered
Garden River,	June 13 - 16, 1979		Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence		
Middle Neebish Channel &	June 21 - 28, 1979		Upstream from the 1978 section located near the Cell Dock permanent Water Level gauge structure		Table 3.63
Field Point	June 21 - 28, 1979		Across Munuscong Channel downstream of the Middle Neebish Channel Section		Table 3.64
Garden River, (See Subsection 3.22)	July 23 - 29, 1980	To provide data to calibrate an on-going Math Modeling Program on the St. Marys River; to determine flow distribution around Sugar Island; to determine flow distribution from Lake Nicolet into West Neebish and Middle Neebish Channels	Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence	Conventional	Table 3.65
Frechette Point &			Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island		Table 3.66
Rock Cut			Across West Neebish Channel, from MI mainland to Neebish Island		Table 3.67

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Frechette Point &	Oct. 2 - 3, 1985 Sept. 9 - 11, 1986	To obtain data for computing the flow distribution around Sugar Island	Lower end of the Little Rapids Cut Channel, from Frechette Point to Sugar Island	Moving-boat	Tables 3.68 & 3.70
Garden River **(See Subsection 3.23)**			Northeastern shore of Sugar Island to Canada, about 2500 ft. downstream of Garden River confluence		Tables 3.69 & 3.71
U.S. Power Canal, **(See Subsection 3.24)**	Oct. 15 - 19, 1987	To update the hydraulic rating of the Compensating Works	In the U.S. Power Canal, at Sault Ste. Marie, MI	Conventional	Table 3.72
Upper Gate &	Oct. 15 - 23, 1987		1500 ft. upstream of the Compensating Works, from north pier of U.S. navigation locks to south pier of Canadian navigation lock		Table 3.73
Fishway Flow Metering	Oct. 14 & 17, 1987		Downstream of Gate #1	Wading	Table 3.74
Compensating Works **(See Subsection 3.25)**	July 25 - Aug. 3, 1989	To verify the ratings for various gate settings and combination of gate settings of the Compensating Works	Foot of St. Marys Rapids, below Compensating Works, between U.S. Government Plant north tailrace dike and the eastern tip of Whitefish Island	Conventional and Moving-boat	Tables 3.75 - 3.76

TABLE 3.1 Summary of St. Marys River Discharge Measurements (cont'd)

NAME OF SECTION	PERIOD	PURPOSE	LOCATION	MEASUREMENT TECHNIQUES	DISCHARGE MEASUREMENTS*
Compensating Works: Upper Gate, **(See Subsection 3.26)**	Sept. 12 - 20, 1990	To verify the ratings for various gate settings and combination of gate settings of the Compensating Works	1500 ft. upstream of the Compensating Works, from north pier of U.S. navigation locks to south pier of Canadian navigation lock	Conventional and Moving-boat	Tables 3.77 & 3.78
U.S. Power Canal &			In the U.S. Power Canal, at Sault Ste. Marie, MI		
Lower Rapids			Foot of St. Marys Rapids, below Compensating Works, between U.S. Government Plant north tailrace dike and the eastern tip of Whitefish Island		
Compensating Works: Upper Gate, **(See Subsection 3.27)**	Aug. 14 - 23, 1991	To verify the ratings for various gate settings and combination of gate settings of the Compensating Works	1500 ft. upstream of the Compensating Works, from north pier of U.S. navigation locks to south pier of Canadian navigation lock	Conventional and Moving-boat	Tables 3.79 - 3.81
U.S. Power Canal &			In the U.S. Power Canal, at Sault Ste. Marie, MI		
Lower Rapids			Foot of St. Marys Rapids, below Compensating Works, between U.S. Government Plant north tailrace dike and the eastern tip of Whitefish Island		

* See Appendix C (under separate cover)

TABLE [illegible] Summary of [illegible] River Discharge Measurements (cont'd)

DISCHARGE MEASUREMENT DATA	MEASUREMENT TECHNIQUES	LOCATION	PURPOSE	PERIOD	PERTINENT SECTIONS
[illegible]	[illegible]	[illegible] Compensating Works [illegible] north part of [illegible] north [illegible] navigation [illegible]	[illegible] Compensating [illegible]	[illegible] 20, 1953	[illegible] (See Subsection [illegible])
		In [illegible] Power Canal [illegible]			[illegible] Power Canal
		[illegible] Plant below [illegible] between [illegible] Plant north [illegible] the eastern tip of [illegible] Island			Lower Rapids
Tables [illegible]	Conventional Method	[illegible] upstream of the Compensating Works [illegible]	[illegible] of discharge [illegible] gate settings of the Compensating Works	[illegible]	Compensating Works Gate (See Subsection [illegible])
		In [illegible] Power Canal [illegible]			[illegible] Power Canal
		[illegible] Rapids, below [illegible] Compensating Works [illegible] Plant north [illegible] the eastern tip of [illegible] Island			Lower Rapids

* See Appendix C [illegible]